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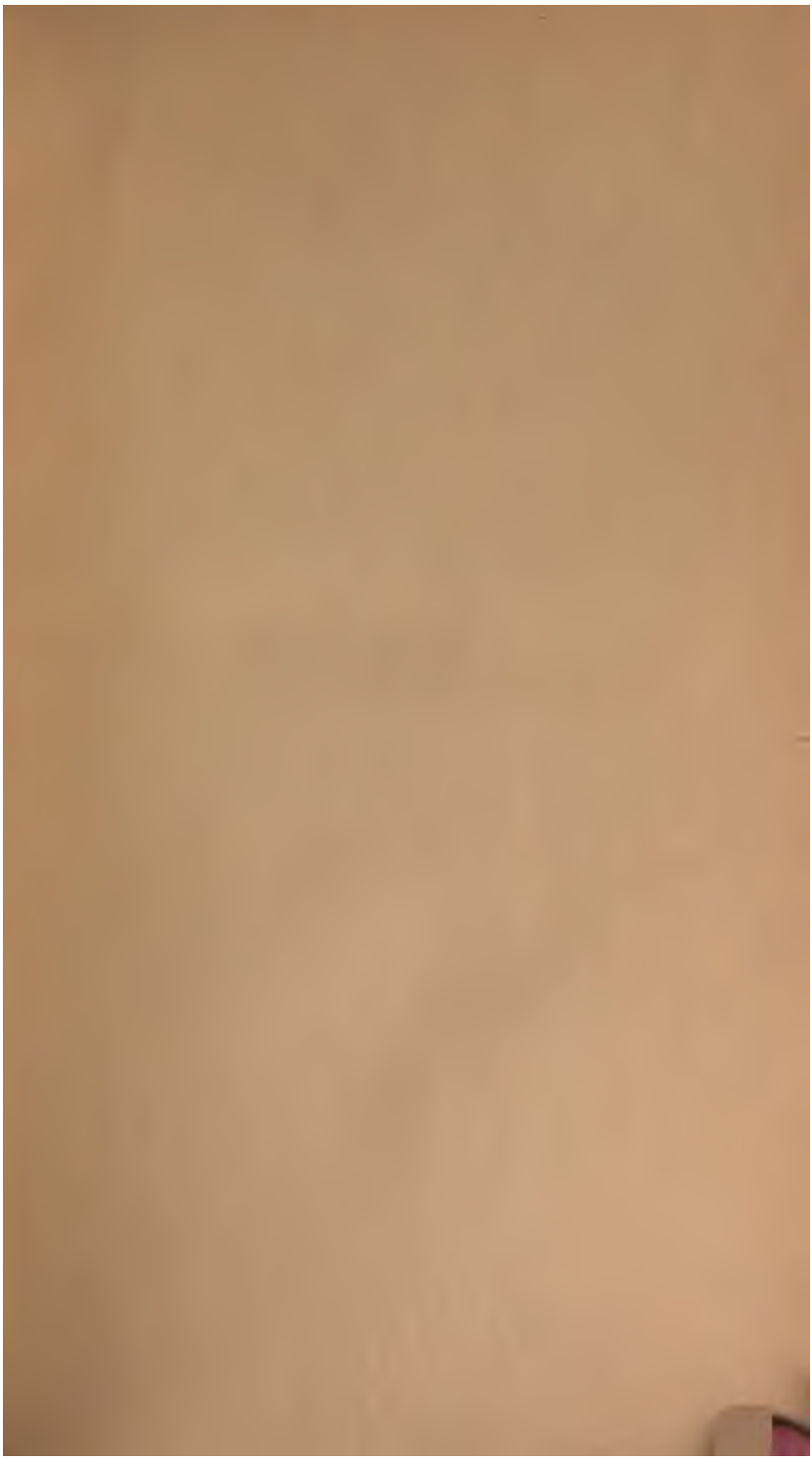

CHEMISTRY

APPLIED TO

ARTS

AND

MANUFACTURES.

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IN FOUR VOLUMES.

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PREFACE.

A TREATISE on Chemistry applied to the Arts, cannot be a treatise on each art in particular. An undertaking of that nature would not only exceed the ability of any individual, but such a work must necessarily abound with tedious repetitions. The air, water, heat, light, act according to the same laws in the hands of every class of artists; and it is sufficient to point out the respective properties of all these agents, and the law of their action, to

give every artist a competent idea of the cause, motive, and principle of his operations.

The best way of illustrating the arts consists not so much in describing their processes with accuracy, as in reducing all their operations to general principles. The description of an art, however correct it may be supposed, is nothing more than the history, the picture of the existing practice. It may, indeed, raise all artists to the same level in point of knowledge, by the communication of the same processes, but it does not enable ingenuity to advance a single step; while science reflects a light on every operation, elucidates all their results, makes the artist perfect master of his

processes, varies, simplifies, and improves them, foresees and calculates all their effects.

A treatise on Chemistry applied to the Arts, is therefore an elementary work; and I shall think that I have attained the object I had in view, if every artist finds in this performance the cause of all his results, and the fundamental rule of his conduct.

A work of this nature could not have been composed till the facts were sufficiently numerous to be compared with each other, and till analysis was brought to such a degree of perfection as to exhibit, in the products of an operation, the cause and the results of all pheno-

nomena. Time, therefore, was requisite to prepare the materials.

Facts existed anterior to the science that was to illustrate, to collect, and to compare them. Science is like the methods of naturalists, which could not be established till the knowledge of a vast number of animals allowed them to examine and compare their principal characters.

But, in order that chemistry might elucidate the arts, it was necessary that itself should have acquired a profound knowledge of all the agents, of their properties, and of their action; it was requisite that all bodies should have been classified, that all their effects should have

been calculated, and reduced to general principles. The conclusion of the eighteenth century accomplished this revolution. Elements before unknown were added to those with which the chemist was previously acquainted; the analysis of air and water came forward to illustrate the action of those two substances; the decomposition of acids afforded an explanation of their principal effects; the fluids of heat and light, those fertile sources of action and of re-action, those primary principles of vitality, took their places among the elements of bodies. Chemistry, which had hitherto been confined to particular operations, became, all at once, a central science from which all things emanate, and to which all things return. Man soon discovered that nature, equally simple in

her principles of action, and fertile in the means of unfolding them, is governed by a small number of general laws; and artists heretofore separated from each other in the vast field of genius, for the first time, perceived that they were united by the closest relations, and that their operations were regulated by principles common to them all.

Chemistry applied to the arts will, therefore, be that science which, from the comparative analysis of the operations of all the arts, will deduce certain general laws, to which the innumerable effects observable in the practice of those arts may be referred.

Considered in this point of view, the chemistry of the arts may be pronounced

a pharos, which the hands of man has erected in the sanctuary of the operations of art and nature, in order to throw a light over all its details.

But the chemistry of the arts is not confined to the elucidation of what is already known, or to the improvement of what is already practised. It daily creates new arts; and within the period of a few years we have seen it teaching new methods for the bleaching of cloths, manufacturing ammoniacal salt, alum, and copperas; decomposing marine salt for the purpose of extracting soda; enriching the art of dyeing with new mordants; forming saltpetre, and refining it by the simplest processes; composing powder by methods the most certain and

expeditious; reducing the tanning of hides to its genuine principles, and abridging its operations; improving the extraction and working of metals; simplifying the distillation of wines; economizing the means of producing heat; establishing the combustion of oil, and lighting our habitations on new principles; and furnishing us with expedients to soar aloft in the air, and to consult nature three or four thousand fathoms above the surface of the earth.

Before chemistry had reduced the numerous operations of industry to general principles, the arts and manufactures were, if I may so express myself, the appanage of certain nations, and the property of a few individuals; the most

impenetrable secrecy covered every process with the veil of mystery; forms and practices were transmitted as an inheritance from one generation to another. Chemistry has revealed every thing: it has rendered the arts the patrimony of all; and in a short time we have seen the nations by whom this science has been cultivated enriching themselves with the establishments of their neighbours. The preparations of lead, copper, and mercury; the works in iron; the fabrication of acids; the manufacture of stuffs; the printing of colours upon cloths; the composition of crystals, of baked earths, of porcelains, &c. all these have been drawn forth from the womb of mystery, and are now common property.

Thus, in the course of twenty years, chemistry has created various branches of industry; it has improved a still greater number, and made public almost all the processes of the arts.

But while we admit that chemistry has rendered important services, while we hope that it will perform still greater, when its researches, enlightened by the progress of science, shall be more particularly devoted to the arts; we cannot help forewarning the artist and the manufacturer of the abuse which is made of the term *chemistry*, and intreating them not to place a blind confidence either in all the works which bear that name, or in all those who assume the title of *chemists*. Chemistry has its adepts and its

empirics, as well as the other sciences. The manufacturer might easily ruin his fortune and his reputation, were he to regulate his conduct, or ground his speculations on calculations made in the closet, on the petty results of the laboratory, or on specious, but delusive advertisements.

Innovations, however advantageous they appear, should not be introduced into manufactures but with the greatest circumspection. Before we change what exists, before we alter what already prospers, before we derange a course of operations under the idea of improving them, experience ought to have decided the superior advantages of the projected changes, and the new process should

have received the sanction of practice, and even the approbation of the consumer.

Without these salutary, prudent, and necessary precautions, which the theorist is pleased to term obstinacy, prejudice, and ignorance, the fairest establishment is soon disorganized. The manufacturer wavers for some time in doubt, darkness, and uncertainty; and, after ruinous experiments, he is glad to return to his original method, and to re-establish his reputation on its former basis.

But though I commend the cautious prudence of the manufacturer, who, almost inaccessible to new ideas, adopts no change till it has undergone the test of

practice and of his own experience; I blame the obstinacy of him who rejects, without examination, all the improvements that are proposed to him: for he who does not endeavour to keep pace with the arts will soon be left behind. He finds that his productions gradually become disliked; he can no longer afford them at so low a price as his competitors; and instead of imitating them, he censures their new processes, which he treats as dangerous innovations; he petitions government for regulations that the fabrications may be rendered uniform, he demands that it may be shackled with inspectors, and loudly invokes every thing that can retard the enlightened progress of the arts.

In consequence of this fatal blindness, we have beheld the decay and ruin of establishments which had flourished for ages; and, from the same cause, we daily behold the arts emigrating from city to city, or from nation to nation.

The manufacturer is therefore placed between two rocks; that of blind credulity, which risks his fortune in hazardous speculations; and that of obstinate mistrust, which undermines the foundation of his establishment by preventing the introduction of methods that are capable of improving it.

True wisdom, therefore, consists in bestowing due attention on all discoveries; in making trial of every thing that

has the sanction of experience, or the testimony of professional men in its favour; but not to adopt as a method of fabrication any that has not undergone the test of a sufficient practice.

I have ever considered it impossible for the chemist to unite in his laboratory all the elements of calculation on which the manufacturer ought to operate, before he decides on any subject. The workmanship, the expences of establishments, the interest of capital, the facilities of sale, the taste or the caprice of the consumer, the nature of the soil, the supply of fuel and primary materials, are all data which are necessary to be known, weighed, and calculated; and the manufacturer alone is able to pro-

cure sufficient information, in order to obtain results on which to ground his decision.

In this whole affair, then, there are two distinct objects, that of the chemist, and that of the manufacturer; the first proposes, the second judges and decides. What appears most advantageous to the chemist may not be so to the manufacturer, because the chemist consults nothing but science, while the manufacturer is acquainted with existing circumstances, compares the expence with the profit of the improvement, weighs the results of the two processes, consults the taste of the consumer, and grounds his decision on a multitude of facts and circumstances which the chemist can neither know nor appreciate.

Thus the chemist and the manufacturer have it in their power to render mutual assistance to each other: but each must confine himself within those limits which the nature of their respective studies has chalked out. Any inversion of this order of things cannot fail to produce confusion, and lead to results ruinous to their fortunes, and discreditable to science.

But vain would be the attempt to improve the arts by means of chemistry, to raise them to that superiority on which depend the glory and the wealth of states, unless other causes co-operated with science to insure their prosperity.

The most powerful cause of the success of a manufacture is, doubtless, to be found in the good quality of the articles, and the economy of their fabrication: but the most intelligent man will behold the germs of his industry languish under his hands, if other protecting causes do not facilitate their expansion.

Supposing a person to be in possession of all the knowledge and information requisite to form and to direct an establishment, it is further necessary for its
merity, that it be formed in a favour-
tion. A branch of industry
be fixed indiscriminately, or at
on this or that particular spot;
e adapted to each has been mark-
the very nature of its operations;

each has its peculiar soil, and not without the heaviest inconveniences can this natural order be inverted.

The importance of local situation is particularly great for all the arts whose productions are low in price, and in which the workmanship is a very inferior consideration. Such should be established near the places from which they are supplied, and at no great distance from those where the products are consumed, because they can neither bear the carriage of the primary material, nor that of the manufactured article.

The power of locality is less absolute over objects of luxury. Thus a pottery for coarse wares should be erected on the

stratum of clay of which they are made, and not far from the places where they are consumed, or of canals and rivers which facilitate their conveyance; whereas a porcelain manufactory may flourish in the centre of a large city, because there the workmanship is every thing, and the primary materials scarcely enter as an element into the price of that pottery.

All the arts in which the workmen, the materials, and the means are collected with difficulty, ought perhaps at first to be established in cities. There men, drawn together by necessity, exist by their industry alone; they form, if I may be allowed the expression, a common fund of all their resources, and di-

vide all the operations among them, in order the more speedily to accomplish their purpose. It would even appear that such of the arts as require great intelligence, and a perfect taste, cannot flourish but in the midst of great cities, because there only can we hope to find the necessary resources.

Not only are certain situations improper for the supply of the consumption and the workmanship of a manufacture, but there are places, which, though possessing all these advantages, are inimical to certain kinds of manufactures, for reasons deduced from the very nature of the soil. Thus a spot which presents great resources for agriculture, and supplies all its inhabitants with rea-

dy means of subsistence, cannot support any manufactures but such whose existence is naturally connected with that of the productions of the earth. On these principles it is that manufactures of linen, wool, silk, hemp, and wine, instead of being prejudicial to agriculture, multiply its resources, provided they engage the husbandman only during that season of the year in which they require his attention. Establishments for mechanical arts, or objects of luxury, would cut up territorial prosperity by the very roots.

We sometimes observe manufactures which seem to flourish for some time, though placed in situations that would appear unfavourable to them. This prosperity is but a forced state; the fortune

of the proprietors, the skill of the managers, the favours of government, may prolong their existence to a few years; but as it is not in the power of man to remove the causes of ruin which are incessantly in action, their power overwhelms all his efforts; and after an arduous struggle, we behold the downfal of establishments, to whose prosperity nothing was wanting but the choice of a more suitable situation. Thus glass-houses, foundries, and other works which consume a great quantity of fuel, are arrested, at their very outset, by the hand of death, when they are established at a great distance from forests or coal mines.

We have already observed, that the arts of luxury and manufactures of stuffs

may thrive in cities, where a numerous assemblage of individuals affords them resources which cannot be expected in other situations. But how are these advantages counterbalanced by the inconveniences which attend the crowding together of so many workmen on so small a spot! What an awful spectacle to behold twenty or thirty families, whose existence essentially depends on the prosperity of a manufactory! A political revolution, a change in the prevailing taste or fashion, a declaration of war, paralyse the activity of these manufactures; and we see, almost in a moment, the industry and livelihood of forty thousand persons checked and cut off amidst the anguish of penury and despair.

I have always considered these alarming assemblages as one of the greatest calamities attendant on the progress of civilization, and I think it wise and prudent policy to prevent them. Not only do they every moment threaten the public tranquillity, but they endanger the fate of the art itself, since they expose it to the extremely variable chances of all those events which act so powerfully on the population of cities.

To combine the exquisite taste that exists only in cities with the facility and economy of workmanship which are found in the country, without running the risk of the fatal consequences arising from the crowding together of workmen which we have already noticed, it is my

opinion that the proprietor of an establishment should reside in cities, while the hands engaged in the execution may be dispersed in the country. By these means the former enjoys daily opportunities of consulting the taste of the consumer; he is surrounded by artists and men of science, who enlighten him; he possesses all the facilities that can be desired for obtaining supplies of the primary material, and for the consumption of his productions; he causes the articles, made at a low price in the country, to be first prepared under his own inspection; he increases or contracts his business, according to circumstances, and upon the simple calculation of interest, because he is not afraid lest the husbandman, who gives to manufactures only so

much time as he cannot employ in agriculture, should fall into a state of lethargic indolence, in consequence of the cessation of his engagement in the former branch of industry.

If we direct our attention to the manufactories which have flourished for a long period of time, which have been unassailable by the storms of revolutions, the caprices of fashions, and the versatility of the laws and regulations imposed on commerce, we shall find them all situated in the country, where the barrenness of the soil, and the inclemency of winter, prevent the inhabitant from following without interruption the employment of cultivating the earth; and experience teaches us, that though the means of

execution are less perfect in the bosom of mountains, and beneath the roof of thatch than in cities, yet the productions manufactured there are offered in all the markets of Europe, at a lower price than those of cities; the reason of which is, that as workmanship is there lower, it balances with advantage against the more imperfect means of execution.

But the advantages of local situation, and the intelligence of a manager, cannot insure the prosperity of an establishment, unless the protection, the encouragements, the laws, and the regulations of a state are calculated upon the true interests of manufactures.

All governments are, doubtless, willing to protect the arts and commerce; but there are few whose conduct, in this particular, comes up to their good intentions. A government that is truly the protector of industry is ever attentive to the arts, and its expedients to facilitate their developement, and to insure their prosperity, are reduced to the following: To render the supplies of primary materials easy, and to facilitate the consumption; to grant premiums on exportation, that the productions of the national manufactures may find their way into all the marts of Europe; to employ its credit with other governments for the purpose of obtaining a knowledge of improvements, and new processes wherewith to enrich its own country; to

determine, and to maintain with energy, the relation which ought to exist between the workman and the master; to consult the soil, the climate, the character of the inhabitants, and the interests of agriculture, that it may grant none but a judicious protection, &c.

Consistently with these principles the French government ought to devote its particular attention to the manufactures of wool, silk, flax, hemp, the distillation of wines, the making of earthen-ware, and all those articles for which the primary materials are abundantly supplied by the soil. It is only from a deplorable inversion in this order of things that we have, for half a century, seen it encourage the cotton manufactures, without

reflecting that the fate of these establishments, supplied with materials from abroad, was liable to be affected by all the chances of revolutions, by all the intrigues of cabinets, by all the variations of laws relative to the customs, and that the manufactures essentially territorial would suffer so much the more by this competition, as, in order to encourage, multiply, and consolidate these infant establishments, it was necessary to grant premiums, to prohibit the importation of analogous productions, and to direct all the capital, the science, and all the hands in the country to this truly exotic branch of industry.*

* I am only speaking of what ought to have been done fifty years ago. Now that the cotton manu-

It is likewise in consequence of viewing objects in a wrong light that governments strive to establish every branch of industry in their respective states, without reflecting, that every country, from its position, its climate, the nature of its soil, and the character of its inhabitants, has certain arts and manufactures which

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factures form a considerable branch of our industry, now that they employ nearly two hundred thousand persons, it is, doubtless, the duty of government to protect them. But was it wise policy to establish them in France? Has not their introduction been detrimental to the essentially national manufactures of linens, woollens, silks, &c. Would not the government have acted more prudently, had bestowed encouragements on the above-mentioned manufactures, and left those of cotton to our rivals, as means of exchange against the productions of our industry and our soil? There lies the question.

belong to it, and form, as it were, its inheritance; without reflecting that a nation desirous of doing every thing, and having every thing, separates, and cuts itself off from the rest of nations, that it reserves no medium of exchange, and that the true relations of commerce cannot be established, except upon the respective exchange, either of the productions of the soil, or of the productions of industry.

It is further a necessary consequence of that forced state, and of that false direction which is given to industry, that governments conceive themselves obliged to prohibit the importation of the productions of foreign manufactures. Besides these considerations that such

prohibitory laws would be unnecessary, were each nation to confine its industry to such objects alone as nature herself seems to have pointed out; and that it would then be sufficient to lay a duty on importation proportionate to the prime cost of the articles, on all similar productions of foreign manufacture; these laws organize fraud, corrupt the morals of a portion of the people, and have a prejudicial influence on the progress of the arts; for the manufacturer does not strive to improve, unless he has before him articles of a better or more economical manufacture than his own. Take away these objects of comparison, and content with his work, because he finds means to dispose of it, he falls asleep in his state of mediocrity.

We daily hear people assert the necessity of making *regulations for manufactures*, and re-establishing inspections, in order to render them flourishing. Such contend for the propriety of restoring the system of regulations adopted by the great Colbert. They of course do not see, or affect not to perceive, that we are in such times and situations as cannot be compared to the period in which that celebrated man appeared. The arts were then either unknown or in their infancy; in this feeble state it was doubtless necessary to assist, to fix them, and to establish their credit; and as soon as any method of fabrication was ascertained to be advantageous, it was prudent to make a law of its execution, in order to preserve and to extend its

practice. Had it not been for this wise precaution, the first steps of the artist, yet unsteady, would have led him astray. But now that all operations are calculated, familiarised by practice, and elucidated by the sciences, the manufacturer has released himself from his leading-strings, and his further advances require his perfect independence. Regulations for manufactures, by confining the artist to one uniform course, leave no scope for his imagination. To the too rigid observation of them it is owing that we have been distanced in the career of manufacturing industry by a rival nation. France never exerted all her genius till those barriers were broken down: since that moment the manufacture of cloths has been improved, the

fabrication of casimeers has become known, and the freedom given to manufacturers has introduced a variety of stuffs, and an improvement in the processes, which have in a short time raised our fabrics to a level with the best in Europe. Regulations for manufactures may indeed secure the present, but they ruin the future, and form a code of routine and of prejudices.

I know that all the manufacturing towns where industry languishes, loudly call for regulations for manufactures; I even know that almost all of them ascribe the decline of their sale to the suppression of these regulations; but I likewise know, that were they to look round them, they would see either that

the manufacture has removed to other places, because its establishment found there certain advantages; or that the consumer has formed other connections, because he can be served at a lower price; or that the fabric has been improved in other manufactories, while theirs has remained the same: or that political movements, or treaties of commerce, have altered their relations with the nations which consumed their productions; or finally, that the capricious taste of the consumer has led him to prefer other articles. I have no doubt that, on examining all these causes, the honest manufacturer would find which of them it was that operated to his disadvantage, and that instead of hoping to promote, by regulations, the progress of

discovery, and the efforts of imagination, he would strive by the application of new processes to raise his manufacture to the state of prosperity from which it had fallen.

Some of them thought that they pleaded the cause of the consumer in defending that of regulations; but this is also an error which it is of consequence to refute. The consumer is the best judge of the merchandize which he purchases, and it is the interest of the manufacturer to supply him with a good commodity. The relations between the two classes of men are not permanent, inasmuch as they are established on their respective interests. Regulations and inspectors may, indeed, insure an inva-

riable fabrication, but this is not always what suits the consumer; for if he wants a slight and cheap stuff, why should he be obliged to buy one that is strong and expensive, and that he has no intention of using?

In my opinion, the liberty of making stuffs of all qualities, and of all dimensions, is exclusively to the advantage of the arts and of commerce: for industry cannot unfold its resources, unless it has sufficient latitude to apply all its methods. The interest of industry consists less in the making of a rich and expensive dress, which is kept for a long time, than in the fabrication of more simple garments which consume a greater quantity of the primary materials, employ

more hands, and occasion a quicker circulation.

Regulations are necessary only for objects of which the mere inspection will not enable you to form an opinion: such as works in gold and silver. It is the province of the government to fix the quality, and to render the composition uniform. The government might likewise require each manufacturer to stamp his name on all his goods, as a warranty to the consumer; but this is the utmost that it ought to do.

What a benefit would a government confer on the arts, if, instead of forming regulations, and appointing inspectors to superintend their execution, it were to send into the manufactories the most skilful persons to improve the

methods of fabrication, to introduce the ameliorations of which they are susceptible, and the processes and machinery which are adopted in foreign establishments!

Our observations concerning regulations may be applied without exception to trading companies or corporations; for these institutions, under the pretext of furnishing society with managers of manufactories skilled in the principles of a judicious practice, rejected such persons whose rising talents excited the jealousy of their examiners, to whom they were likely to become rivals. But what will appear most extraordinary is, that these institutions should have subsisted so long as they did, though they were daily accused and condemned

by experience. At Paris, for example, industry took refuge in the fauxbourg Saint Antoine and in the Temple, for no other reason than because companies and corporations were there unknown.

After having shewn what the artist is capable of performing, and what it is the duty of government to do for the prosperity of the arts, it remains for me to make a few remarks on the influence which belongs to the consumer. As the artist works only for the consumer, he should naturally adapt his fabrication to the tastes, and even to the caprices of the latter. The consumer may therefore be considered as the actual regulator of the operations of the manufacturer. He directs the workman in his plans, and in their execution; and if

he has taste, he rejects all that is not perfect, and occasions the artist insensibly to become familiarised with the beautiful; but if he is deficient in taste and intelligence, he causes him to deviate from the proper track.

If the consumer were to order and to purchase none but perfect commodities, the workman would soon turn no other out of his hands. If, on the contrary, the consumer cannot distinguish a faulty from a faultless production, the artist having no interest to study perfection, will all his life be satisfied with turning out crude performances. The consumer, therefore, forms the artist by the purity of his taste, and the correctness of his choice; but institutions form the consumer; and not till a good education,

the study of the arts, and the sight of good models, have prepared a generation, can we hope to find enlightened consumers.

It was long before I concluded what order I should adopt in a Treatise on Chemistry applied to the Arts. I thought at first, that it would be most adviseable to class the arts, and to compare their operations for the purpose of going back to principles. But I found that I should lead myself into repetitions, and swell out my work to an unnecessary bulk. For instance, as air, fire, water, act in almost all the arts, I should be obliged to treat of their action in discussing each art, and to recur every moment to principles which had

been previously explained. I resolved, therefore, in the first place, to establish the genuine principles of the science, and to class under each all the operations of the arts emanating from it; being convinced, that by following this method all the arts would naturally range themselves under that law which governs their operations.

To this end I shall begin with stating the principles of chemistry, and the general laws obeyed by bodies in their reciprocal action. I shall then point out the modifications introduced in these primitive laws of nature by everacting causes, such as the pressure of the atmosphere, the action of heat, the influence of vitality, the effort of elasticity, &c.

After fixing the fundamental basis of all operations considered in the natural order, I proceed to the means which art is capable of employing in its turn, to facilitate or modify the action of these same laws, and to communicate motion to these powerful agents of nature.

This first portion of my work, therefore, embraces not only the knowledge of the laws of nature in the reciprocal action of bodies, but it likewise teaches the means by which the chemist is enabled to direct, to vary, and to study their effects.

Having discussed the general laws of chemical action, and the means employed by the artist, either to apply them to

the bodies on which he operates, or to calculate the results, it seemed natural to me to follow up these fundamental laws, with the description of the principal bodies on which chemical action is exercised; and I thought it right to exhibit them in their highest degree of simplicity, for the purpose of studying the better their peculiar characters.

This second part of my work comprehends the description of earths, of alkalis, of metals, of sulphur, of phosphorus, of carbon, of the gases, &c. I have also added the bitumens, the oils, the resins, and the acids, because, though these are compound substances, some are employed as primary materials, while others are in the hands of the che-

mist his principal agents of action, of composition, and of decomposition, and by their combination form compounds the best known, and the most useful in the arts.

In these two first parts I have naturally been led to notice a great number of arts, and to illustrate their principles. Accordingly, the art of applying heat, considered with relation to the construction of furnaces, the difference of various kinds of fuel, and the nature of the substances submitted to the action of the fire; the art of reducing earths to such a state of purity as to render them fit for the purposes to which they are applied; the art of extracting metals from their ores, and separating them from their

natural alloys; the art of making charcoal, of preparing sulphur, of forming all the acids; the art of extracting alkalis, oils, mucilages, bitumens, the tanning principle, the juices of vegetables, gelatine, and of appropriating them to the uses of commerce; all these objects naturally found a place in the two first parts.

After having unfolded the general principles of chemistry, and explained the properties and characters of the bodies on which chemical action is exercised, I had nothing more to do than to set these different substances at work, to form mixtures or produce combinations, and to exhibit in one grand picture, the fabrication of all the chemical products in common use in the arts.

Following this course, equally simple and natural, I have been led to treat successively: 1. Of the mixture of gases with each other, which gave me occasion to examine the atmospheric air, and the nature of its principles; 2. Of the mixture of earths, with regard to vegetation, and of their combination in the art of making earthen-ware, glass, &c. 3. Of the alloy of metals, of their oxydation, and of their reduction, which embraces a great number of operations, and describes many important preparations for the arts; 4. Of the fabrication of all the salts employed in the manufactures, or used for domestic purposes; 5. Of the combinations of sulphur, of oils, of tan, of resins, of coloring principles, &c.

In treating of each preparation, I thought it necessary to exhibit, at the same time, the method of employing it, the cause of its effects, and the differences of action, which depend on modifications made in its composition, or the manner of using it.

I have not considered myself bound to give, when treating of each art, those numerous details of execution which constitute the practice of the workman, rather than the science of the artist. I conceived that, in the application of chemistry to the arts, a writer ought to confine himself to an exposition of the chemical principles on which art is established; I thought that in a work of this nature he ought to enlighten the

steps of the artist, and not pretend to mark out for him a purely mechanical track, in which the practice of a few days gives him more knowledge than books are capable of imparting. In a word, my object was to enlighten the artist, not to form the workman; and I constantly bore in mind that I was writing for the artist who executes, and not for the apprentice who is just entering the shop or manufactory.

Exclusive of the consideration that this method of treating chemistry applied to the arts, is the only one that allows the subject to be compressed within proper limits, I was induced to adopt this plan by the opinion I have long entertained, that the intelligence which

elucidates practice must succeed the latter. I am, in fact, convinced, from my own experience, that the man who is already acquainted with the mechanical and practical part of an art, receives instruction with much more advantage than another who is neither in the habit nor practice of its operations. For the latter every thing is abstract, because the principles he is taught apply to nothing that he already knows, and are either soon obliterated from his memory, or take a wrong direction there. The first, on the contrary, reflects on his own experience all the light that is transmitted to him; he sees in his practice the confirmation of all that is told him; he refers all that is said to all that he does; he compares the theory with his own

operations, and in a manner identifies it with them; in a word, the doctrine which is taught him is like a new soul which animates all the labors of a manufactory, where before he only beheld movements without knowing their principle, and effects without being sensible of their cause.

But, I repeat, that it was my design to give a work of principles, and not a collection of formulæ or processes of manipulation. I have continually had it in view to enlighten the artist by explaining to him the cause of all the results which he observes in his operations, and the nature of the substances which he employs. I write not for any art in particular, but I write for all, and en-

deavour to reduce them to common principles.

Indeed the simple arts, which consist only of a single operation, or receive action from only one agent, are treated of in this work with all the necessary developements; but the complicated arts, that is, those which demand the successive, or simultaneous action of air, water, and fire, on metals, earths, or organized substances, could not be described at such length; and I have merely established their principles, which will be found scattered in different chapters. I had no other method of avoiding repetitions.

This treatise on chemical principles applied to the arts will soon be followed

by the description of some very complicated arts; and in the course of the present year, I intend to publish the *Art of Making Wine*, and the *Art of Dying Cotton red.*

In all these various particular treatises which will succeed the publication of my *Chemistry applied to the Arts*, I shall give all the details necessary to render the processes easy of execution, so that they may be considered as a sequel to the principles which have been established in this work.

This book then, such as it is, may be considered as a Treatise of Chemistry, following the same course and the same method as that important science—a

science, the study of which it may facilitate, all the principles of which it exhibits, at the same time that it describes the preparation and the uses of almost all the substances whose properties are employed in the arts.

In perusing this work it will soon be perceived, that I have neglected to submit the series of acids, and that of earths and metals to the methods of classification. In describing about twenty bodies which resemble each other in general properties, I did not think it necessary to divide them into genera, in conformity with the comparison and analogy of certain secondary characters. Not only the memory is not burdened by so small a number of bodies, in whatever

order they may be presented, but experience has taught us that the progress of science daily deranges these systematic combinations.

Though in the last thirty years I have formed many establishments, and have visited a far greater number, yet there are many arts of which I have not been able to acquire a sufficient knowledge to give satisfaction to myself. There are others which I have never enjoyed opportunities of seeing, and respecting which I have only consulted memoirs or accounts more or less correct. I have even been obliged to omit altogether certain articles of manufacture, because I was apprehensive lest I should commit or propagate error.

My work is, therefore, imperfect; but, such as it is, I think it useful, and under this conviction I submit it to the Public.

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CHEMISTRY

APPLIED TO THE ARTS.

BOOK I.

Of Chemical Action.

ALL bodies have a reciprocal action on each other, which produces modifications in their forms, or changes in their nature and constitution.*

It is this action, the means, cause, and results of which the natural philosopher and chemist are solicitous to discover.

* By the *constitution of bodies*, I mean the state in which they are accustomed to appear at the temperature of the atmosphere. A body changes its constitution when it passes, for example, from the liquid to the aëriform or solid state, or from the solid to the liquid state.

The natural philosopher ascertains the action of the properties of such bodies as can be determined without altering their nature: such are gravity, elasticity, temperature, motion.

The chemist studies the more immediate and reciprocal action of bodies, and particularly notices all the phenomena which change their nature or their constitution.

Physical action operates on bodies without altering their nature. Chemical action embraces all the phenomena which exhibit combinations and decompositions.

The natural philosopher takes a comprehensive survey of whole masses, and calculates all their properties. The chemist, on the other hand, studies the operations of their particles, observes their reciprocal action, and seeks to discover all the changes that may occur.

Thus all the operations of nature or of art, which occasion changes in the nature of bodies, fall within the province of chemistry.

How immense is the empire of chemistry! It embraces in its studies all the phenomena which nature presents to our view, in the infinite variety of her productions, and all the pro-

cesses of the arts for which we are indebted to human ingenuity.

By the term *affinity*, the chemist expresses the chemical action which bodies mutually exercise on each other, when they are at imperceptible distances. The tendency of masses to approach each other the natural philosopher denominates *attraction*.

Affinity is, therefore, the basis and regulator of all chemical operations: we should consequently first endeavour to obtain an insight into this general law of nature, that we may be enabled to comprehend all the phenomena that proceed from it.

We have defined affinity to be a power of action which belongs to every particle of matter.

This power of action considered individually in a particle, is not equal for all the particles of a different nature that may be presented to it: the particle *a* shall very forcibly attract the particle *b*, with which it shall form a solid combination, whereas it shall refuse to unite to the particle *c*.

From this variation in the power of affinity, it follows: 1. that the particles which form

compounds are united and retained by a power of combination more or less strong; 2. that it is possible to separate one or more constituent particles, by presenting, for their combination, a body which has a stronger affinity with one of them, than they have with each other; 3. that very frequently the application of a third body to one already compounded of two substances, so far from causing a decomposition, produces a combination of all three.

Numberless attempts have, at different times, been made to determine the various degrees of affinity belonging to each body. Mr. Kirwan even thought it possible to express by cyphers the power of affinity of each, so that the results of chemical action might be made a subject of calculation.

M. Berthollet has, however, demonstrated, that in every case, when one of the two elements of a combination is displaced, by the superior affinity of a simple body, the separation is neither complete nor absolute; and that the basis of the compound is divided between the decomposing body and that with which it unites, in proportion to the strength of their respective affinities.

It would, doubtless, be highly advantageous, could we, like the natural philosopher, reduce all the facts connected with chemical attraction to one general law. The chemist meets with obstacles which the natural philosopher has not to encounter. The latter is able to measure the distances and ascertain the dimensions of bodies, for the purpose of comparing effects, and deducing from them the two general laws of attraction; but the chemist, who studies and observes only the action of particles, can neither obtain a knowledge of their masses, nor calculate their distances.

Nevertheless a comparison of various observations leads us to conclude, that both *mass* and *distances* are comprehended as elements in the action of affinities.

1. Bergmann, many years since, observed, that if you employ, in several cases, six parts of the decomposing principle, instead of one which would be sufficient to saturate the base, you produce a decomposition which may be considered as nearly total; but if you employ the two bodies, in equal parts, you effect a decomposition only partial and incomplete. M. Berthollet has confirmed, by new proofs, the

influence of masses on chemical action, and has thence deduced this axiom, that the result of a decomposition is proportionate, not only to the strength of affinity of the decomposing body, but also to the quantity of that body.

This fundamental truth of affinities cannot be reconciled to the opinion of those who assume that the power of affinity is not exercised, or cannot be effective, unless between particles that touch each other. It proves, on the contrary, that it extends its action farther than to surfaces, and that it operates at small distances, imperceptible, it is true, to the eye, but which effects justify us in admitting. Messrs. Berthollet, Laplace, and Hauy, have removed every shadow of doubt from this position.

From this general law it follows, that, if you employ but a small quantity of decomposing substance, scarcely any effect is produced; that if, after having decomposed or detached a portion of a body, you add a fresh quantity of the decomposing principle, you will obtain a second result similar to the former; and that by proceeding in the same manner, and by successive additions of the decomposing principle, you will effect a total decomposition.

We must not however, conclude from this principle, that a large mass is sufficient to produce an invariable and complete decomposition: for, in order to estimate the effect, you can only take into account, that portion of the substance which is within the sphere of activity, that is to say, almost in contact.

A very natural consequence that may be deduced from the law which we have here laid down, is, that the intensity of action of the decomposing body must decrease in proportion as that body becomes charged with the base which it displaces; so that an equilibrium is necessarily established between the powers of the two bodies which are disputing for one base. From this principle it likewise results, that the intensity of action of the decomposing body must diminish the more slowly, the greater is the quantity of that body; because, in this case, the portion of the base which is extracted, or displaced, is distributed through a much larger mass—a circumstance which affords an additional proof, that, even in this case, the effect of affinity is proportionate to the mass.

On this principle we likewise explain the reason why it is necessary, in many instances,

to employ a large quantity of decomposing substance to produce a separation that is scarcely perceptible. In this case, the affinity being next to none, must be compensated by a greater mass.

2. The power of distances on the effect of affinities is not less decided than that of masses: but here the influence is in an inverse ratio; for the more closely the particles approximate, so much the more powerful is the chemical action.

Two bodies placed beside each other, have no perceptible reciprocal action; but if you mingle them, and thus bring their constituent particles into contact, you determine their reciprocal action.

The smaller the distances are between the particles, so much the greater is the energy of their action: thus two solid bodies, pounded, generally form a mixture without any appearance of combination; but if you dissolve one or the other of these bodies, its action instantly becomes more powerful, because its division is greater.

The form of particles must have a strong influence on the effect of affinity; for this form

causes them to approximate at a greater or less number of points, and consequently to present a larger or smaller surface to the action; and as there is no sensible chemical action except between parts which are in almost immediate contact, it follows, that it must vary according to the form of the particles.

From this principle we may farther conclude, that, as the variety of form in different particles produces approximations more or less close, the affinities must of course undergo certain modifications from this circumstance: for this form may associate and harmonize so perfectly with a second, that their particles shall come in contact with each other at several points, while they shall have scarcely any contact with those of a third.

CHAPTER I.

Of the natural causes that produce modifications in chemical action.

WERE the affinity of bodies to produce constant, invariable and uniform effects in all cases, and under all circumstances, the phenomena of the operations of nature would be less diversified, and the study of them would be facilitated. Many causes, however, concur to modify its action, and the principal of these we shall now proceed to examine.

SECTION I.

Of the modifications produced in chemical action by the cohesion and insolubility of substances.

All the particles of the same body are bound and held together by an inherent affinity, which is termed *cohesion.*

It is obvious that no separation of the parti-

cles, and no combination with other bodies can take place, unless the power of cohesion be weakened or overcome.

The power of cohesion is so much the stronger in bodies of the same nature, in proportion as the particles are the more closely united.

The power of cohesion is not equal between the particles of bodies of a different nature. Hence it follows, that each body has its degree of cohesion, and that its combination and decomposition are more or less easy.

In order to operate on a solid body, the chemist first divides it by means of a pestle or hammer. By this process he weakens its cohesion, and renders it more accessible to chemical agents.

He frequently employs heat to produce the same effect: for heat separates the particles and diminishes their cohesion.

The first effect of the action of a body which is presented to another, is, therefore, to subdue the force of cohesion. When its affinity is not sufficiently powerful to overcome this resistance, a mixture and not a combination is the result, and each of the two bodies retains its respective properties.

In the latter case, however, though no combination takes place, the cohesion of the body which is attacked must be diminished by the whole force of affinity, which the body presented to it exercises upon it; and it is then *predisposed* or prepared to receive the action of some other body, which alone would have been incapable of effecting either combination or decomposition. Chemistry affords a thousand examples of this nature: almost all the cases of solutions, by which bodies are predisposed for chemical combinations, appear to have no other object.

The cohesion which approximates the elementary parts has a tendency to give to the body that results from their union, invariable and regular figures, which are denominated *crystals*. When a crystal is presented to a saturated solution of the same salt, the crystal is augmented by the application of many similar particles held in solution. This effect is owing to the action of the power of cohesion exercised by the crystal on the particles of the same nature dissolved in the liquid, and the powers of which were before in equilibrium with those of the solvent.

It is the power of cohesion that determines the precipitates which are formed in certain decompositions; for, in all these cases, the cohesion between the particles of the precipitate is stronger than the affinity exercised upon them by the solvent.

From these observations it follows, that the substances brought into action cannot possibly exercise the power of affinity in all their particles, unless they be liquid. In this case, the bodies not only act throughout their whole surface; but, as fast as the parts which are in closest contact, and which consequently are the first to exercise their action, become saturated, they are replaced by new ones which attack the base with all their energy, and an equilibrium of saturation is gradually established between all the parts of the bodies. The ancients, who were acquainted with this truth, expressed it in the following axiom: *Corpora non agunt nisi sint fluida.*

In order that the action of affinity may operate with energy, it is sufficient that one of the bodies be liquid, and that the other be of such a nature as to be easily penetrated: all the particles then come almost into contact, or

they are brought into that state by the progressive solution which takes place in all the parts of their surface, which, by their removal, leave the subjacent strata exposed.

When you displace the body *a* from the combination *a b*, by means of the body *c*, it may happen that the detached body *a* is precipitated, or that it remains in solution, or that it escapes as a gaseous fluid. In the first case, it carries with it a portion of the substance with which it was combined; in the second, the detached principle remains blended with the decomposing body, whose action it moderates, and which is necessarily divided between the separated body and that with which it has formed a new combination; in the third, the detached principle, by its elasticity, evades the action of the decomposing body, the whole force of which is then employed against its base. This last decomposition is the most perfect and complete; because it is the only one in which the affinity of the decomposing body is not modified or weakened.

M. Berthollet has given the appellation of *complex affinity* to what is generally denominated *double affinity*. It takes place whenever

a change of bases is effected by the mixture of two compounds, each formed of two substances.

M. Berthollet ascribes this effect to the force of cohesion, and observes, that in all known cases, the strongest affinity has been discovered to reside in those substances, which possess the property of forming a salt that is insoluble, or may easily be crystallized. Thus sulphuric acid, which is taken up in any soluble combination, being mixed with a composition that has lime, barytes or strontian for its base, will produce a change of principles, for the purpose of uniting itself to those earths.

All soluble combinations of lime, barytes and magnesia, mixed with the carbonates of alkalis effect a change, the result of which is, the precipitation of carbonate with an earthy basis.

In all these cases, the force of cohesion, which is very powerful in bodies that are precipitated or chrystallized, unites to the affinity, which tends to combine the principles that are to form the insoluble body; and it is to the effect of this two-fold action that the change which takes place in the complex affinity must be ascribed.

Thus, when you evaporate a water in which you have dissolved various salts liable to change their principles, you will obtain them in the order of their solubility; and it is by this that you judge beforehand of the changes of basis which may take place.

SECTION II

Of the Modifications produced in Chemical Action by Elasticity.

There are substances, which, at the temperature of the atmosphere, retain an aëriform state, that may be considered as their natural state: so that when you present to those bodies other substances, either for the purpose of producing a solution, or a combination, you have first to subdue their elasticity.

The elasticity of gaseous fluids must therefore be considered as a resistance to combination and solution, which there are but two ways of overcoming:

1. By an affinity superior to this power of resistance.

2. By a condensation of the gaseous fluid, effected by cooling or compression.

When a gaseous fluid has entered into combination with a body naturally solid, you experience the less resistance in displacing it, in consequence of the tendency to resume its elastic state, which it still retains.

SECTION III.

Of the Modifications produced in Chemical Action by Caloric.

We have, thus far, considered the modifications produced in affinities by properties inherent in bodies, such as insolubility, elasticity and cohesion. We shall now direct our attention to the influence of a much more general cause, which seems to be connected with the existence of a fluid universally diffused throughout all nature, and unequally distributed among her various works.* This fluid,

* We here employ the term *fluid*, for the purpose of describing the effects of heat, because we are actually convinced of the existence of a particular fluid, which penetrates all bodies, is combined with them in greater or less quantity, changes or modifies their constitution, passes from one to the other, leaving behind the impression of

when combined with bodies, is called *caloric*: it is this same fluid that, when set at liberty, produces heat, and determines the different degrees of temperature, according to the proportions in which it exists.

The first effect of this fluid in bodies consists in separating the particles, and consequently in diminishing the power of cohesion, which holds them together.

This fluid may, therefore, be considered as the moderator of the affinity of cohesion; and the natural constitution of bodies depends only on the proportions which exist between the power of cohesion and that of caloric.

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cold or of heat, is probably extracted from all by compression, condensation, &c. which, in a word, has its peculiar affinities, and exhibits all the essential characteristics of fluids.

I am aware that philosophers of great eminence consider heat as nothing more than the effect of motion, and deny the existence of a distinct fluid. I shall not discuss the reasons on which they ground their system, because, whether they admit or not the existence of this fluid, is a matter of perfect indifference as far as regards the phenomena of heat. On this subject the reader may consult Count Rumford's Memoirs on Heat, communicated at different times to the Royal Society of London, or to the Institute of France.

We may change, at pleasure, the constitution of bodies by giving them caloric, or by taking it from them. We may even consider liquids as bodies in which the cohesion and the caloric are in equilibrium; whereas cohesion predominates in solid bodies, and caloric in gaseous fluids.

From this principle it must not be concluded, that the quantities of caloric are fixed and determined by the constitution of bodies. Some there are, whose constitution is changed by the slightest alterations of temperature; while others withstand all the means that art is capable of employing. In order to explain this difference, it is necessary to consider caloric as a fluid which has its peculiar affinities, and whose action is exercised on bodies which are held together by a very different power of cohesion; so that, in one case, a small proportion of caloric suffices to produce a change of constitution; whereas, in another, all the resources of art prove inadequate to the accumulation of caloric.

The various substances of which this universe is composed, are, therefore, subject on the one hand, to a general law which tends to

combine them; and, on the other, to a powerful agent which strives to separate them.

These two great powers of nature operating on all bodies, are continually counterbalancing each other in their action; and the changes which take place in their proportions, are the principal cause of almost all the phenomena that engage the attention of the chemist.

It is, therefore, of importance to us to obtain correct notions of the action of caloric on bodies; and I shall now recapitulate such particulars relative to that agent as it is of essential consequence to know.

1. When two bodies of the same nature, but at different degrees of heat, are placed in contact, a mean temperature is more or less speedily established.

Water at the temperature of zero, but still liquid, mixed with an equal weight of water at 60 degrees, forms a mixture whose temperature is 30 degrees.

2. The division of temperature does not take place conformably with the same law when the bodies are of a different nature or constitution.

A metal plunged into water, at an elevated

temperature, acquires in that situation more degrees of heat than the liquid loses: the increase varies according to the species of metal.

From this circumstance it follows, that, in an equal weight, the same quantity of caloric must raise the temperature of metals to a higher degree than that of water.

From the preceding observations it may be further concluded, that bodies of different natures take different temperatures by the acquisition of an equal quantity of caloric.

Let us suppose, for a moment, that a body whose temperature is equal to zero, is plunged into an equal weight of water, at the temperature of 50 degrees, and that the temperature of the mixture indicates 30; it is evident that, as the water has lost only 20 degrees to raise the second body to the temperature of 30, the latter has occasion for less caloric than the former to attain the same degree of temperature; and that consequently its *specific caloric* is to that of water as 20 to 30.

3. When the constitution of bodies is changed by their mixture, other phenomena are then produced. Water at 60 degrees, and water in the state of ice, mixed together in equal weight,

yield a liquid which indicates zero ; the liquid water, therefore, loses 60 degrees of heat, which the solid water absorbs in passing to the liquid state. Hence it is obvious, why the thermometer, surrounded with pounded ice, and plunged into a liquid of a more elevated temperature than ice, continues at zero, as long as any ice remains to be dissolved.

Liquefaction is not the only circumstance in which caloric is combined and absorbed without producing heat. A thermometer plunged into water that is heating, gradually rises till ebullition. It then remains stationary, though the heat be increased, provided the evaporation be unobstructed; and it indicates the same degree as long as there is any liquid water left: but as soon as the whole is converted into vapours, the caloric exercises its full action on the thermometer, and its temperature rises.

From these facts it results, that the caloric is absorbed, and produces no thermometrical effect, whenever a body passes from the solid to the liquid state, or from the liquid to the gaseous state.

The caloric absorbed in all cases again makes its appearance as heat, with its whole

thermometrical action, whenever bodies return from the gaseous to the liquid state, and from the liquid to the solid state. We may even, without impropriety, express Caloric by the terms compression, friction, or condensation.

These two principles relative to the absorption, or the development of caloric are exceedingly fertile in consequences, and afford an explanation of a multitude of phenomena which nature and art present to us in their operations; such as the refrigeration caused by evaporation, the heat produced by the combination of gases, &c.

4. All the bodies exposed to the same temperature are not equally affected by it.

Animal and vegetable substances do not acquire heat till the moment of inflammation, nor liquids till their vaporization. Solids enter into fusion, or evaporate at different degrees.

Among the bodies that have just been mentioned, there are some that become impregnated with heat, but without transmitting it till they have reached the *maximum* of their saturation. Thus animal and vegetable matters may arrive at the degree of combustion, while the bodies near them shall not be sus-

ceptible of the impression of so strong a heat. Metals, on the contrary, transmit heat nearly in the same degree that they receive it.

From these facts it has been concluded, that bodies are, *more or less, conductors of heat;* and numerous applications of this property have been made in the arts.

Not only bodies of different natures are not equally affected by the application of the same quantity of heat, but bodies of the same nature receive from it different impressions. Ingenhousz took metal rods perfectly cylindrical, and of equal dimensions; he covered them with a uniform coating of wax, and then plunged the end of each into oil that was near boiling. He observed, that the wax melted at different heights on the different rods, and from these experiments he concluded, that the heat contracted by metals presented them in the following order: silver, copper, gold, tin, iron, steel, lead.

5. Caloric dilates all bodies, but not in an equal degree.

In general, the same quantity of caloric dilates elastic fluids more than liquids, and these last more than solids.

Liquids differ from each other in regard to their expansibility, which is not proportionate to the elevations of temperature when they approach the state of vapours.

In the experiments hitherto made on the dilatation of solid bodies by heat, no correspondence has been found between the dilatations and the quantity of caloric they are capable of absorbing. Nothing but the fusibility of metals seems to coincide with the dilatations; platina, the least fusible of metals, dilates the least; lead dilates most, and the most fusible glass is also the most dilatable. We may therefore lay it down, with M. Berthollet, as an established principle, that bodies are so much the more dilatable, the less caloric they require to change their constitution from solid to liquid, and from liquid to gases or vapours.

From a long series of experiments, Messrs. Guyton and Prieur deduced a dilatation peculiar to each gas: but M. Gay-Lussac has demonstrated, that all gases, without exception, possess the same dilatability at the same degree of temperature, and that the presence of water in gases occasioned the errors into which his predecessors had fallen.

M. Gay-Lussac concluded from his experiments made on gases reduced to the utmost degree of dryness, that one hundred parts of each of the permanent gases acquired an increase of $\frac{1}{213}$ by every degree of the thermometer from zero to 80.

Vapours follow the same laws of dilatation as gases, provided the temperature be sufficiently elevated to keep them in the elastic state.

It may, therefore, be laid down as a principle, that gases and vapours are equally dilatable and equally compressible.

6. When the caloric escapes from a body highly heated, without immediately entering into combination, it preserves, for some time, its elastic state, and forms what is denominated *radiating caloric*.

Scheele observed that metallic mirrors reflect radiating caloric without contracting any heat, and that the air which it traverses likewise receives none: but that, by degrees, the caloric combines, more or less speedily, according to the nature or the colour of the bodies.

Gases afford a free passage to radiating caloric; and the more expansible they are, in so much higher a degree they possess that property.

Liquids quickly absorb it.

Black substances retain it more easily than others.

7. A disengagement or absorption of caloric is not only occasioned by the changes of constitution which bodies undergo, but combinations and decompositions produce similar effects.

In all the operations of which we are treating, new compounds are formed, that present a capacity for the caloric peculiar to themselves, and must necessarily differ from that of the original compounds from which they proceed. When, for example, a gaseous substance is combined with a solid body, the first abandons the caloric which held it in solution, and preserves only what is necessary for the new compound.

The operations which produce fixation of the gas, are always accompanied with a more or less considerable emission of heat, according to the nature of the new body that is formed.

The simple mixture of two liquids sometimes occasions a *penetration*, which may be considered equivalent to a species of combination, and which causes a change of temperature

without altering the nature of the principles. Thus water mixed with concentrated sulphuric acid produces a great heat, and the mixture takes up less space than is occupied by the two separate liquids.

Were we to travel through the long series of facts from which result combinations or decompositions, we should be thoroughly convinced, that in every one of them there is a production or diminution of heat.

SECTION IV.

*Of the Modifications produced in Chemical Action by Lumic.**

Besides caloric, of which we have already treated, there exists another fluid which fills up

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* By *lumic* I mean the fluid which, when set in motion, yields light, as we term the fluid of heat *caloric*.

It will doubtless be objected that it has not been proved that light is the effect of a fluid any more than that heat is the result of one. This I admit; but as we only direct the attention to the phenomena, and as this supposition has no kind of influence either upon the observation or the results, it cannot but appear a matter of indifference. My reason

the interval that separates bodies, conveys to our eyes the image of the objects around us, and has a powerful action on all chemical phenomena.

Does this fluid emanate directly from the sun, or is it diffused throughout the universe, and set in motion by the rotation of the sun around his axis, and by the collision or brisk action of bodies upon each other? Be these systems founded in truth or error, the impression of objects transmitted by this fluid is so speedy, so rapid, that a second is sufficient to enable the observer to perceive an object at the distance of 80,000 leagues from his eye.

The elasticity of this fluid is extreme; it nevertheless obeys the law of attraction; for, if you present a piece of steel to a ray of light, the ray deflects from the right line, and inclines toward the body.

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for adopting it is, that, by means of this supposition, I comprehend the more easily the effects that are ascribed to heat and light; and that, besides, all the properties of those grand agents coincide with those which we attribute to fluids: they are combined or displaced according to invariable laws. What more can be required in order to class them among bodies?

The influence of light on bodies has ever been acknowledged. Every person knows that a plant appears white in obscurity, that all vegetables reared in a dark place, seek the light, and incline toward the apertures by which it is admitted: that the only part of fruits which is highly coloured is the side exposed to the light; that, in a word, the smell, the taste, the combustibility, the colour, the maturity, the volatile oils, are all products modified in a particular manner by the light. "Were it not for the light," says Lavoisier,* "Nature would be destitute of life; she would be dead and inanimate. By the creation of light a bountiful Deity has diffused organization, sense, and intelligence over the surface of the earth."

If we examine light in a less general point of view, and consider its influence on chemical action, we shall find that it determines various combinations, that it produces decompositions, and that, in many cases, it is disengaged or absorbed consistently with invariable affinities.

When bodies change their dimensions, they receive or emit caloric. If these changes take

* *Traité Elémentaire de Chimie*, p. 202.

place with rapidity, they are accompanied with heat and light; iron becomes hot and luminous by a brisk percussion; oxygenated muriate of potash explodes with sulphur, as do the other bodies that are easily combustible by means of a single percussion, and a considerable quantity of light is disengaged. Two flints struck together emit light; friction exercised on many bodies first produces heat, and afterwards light.

We may lay this down as a principle, that, in all the operations which produce heat, it is possible to obtain light by accelerating them. It is even probable, that, in all cases where there is a disengagement of heat, there is also a production of light, with merely this difference, that it is visible to us when the disengagement is instantaneous, and that it is not visible when the production is slow. In this case, it is the same with light as with caloric, which, in the rapid oxydation of metals, and the speedy combustion of phosphorus, determines an extreme heat; whereas this heat is imperceptible to our organs, when the oxydation and combustion take place more slowly. It is impossible to deny the production of heat in either

case: but, in the one, the emission is instantaneous; in the other, on the contrary, the sum of heat is divided among all the instants of a very long interval, so that its effect is never perceptible.

Lumic is not always intimately combined with bodies: there are some that appear luminous from their nature, such as phosphorus; there are others which become luminous at certain periods of their decomposition, as may be observed in various kinds of rotten wood, and certain species of putrid fish.

There are also bodies in which the combination of lumic is so weak, that it may be disengaged by the slightest friction. The diamond, the blends, the fluates and phosphates of lime, the Bologna stone, and the skin of various animals, may serve to establish this truth.

All bodies are, doubtless, well adapted to the absorption of lumic; but all do not imbibe it in an equal quantity, nor do all form with it a combination equally solid. There are even some which, when saturated with light by the rays of the sun, retain for some time the property of shining in the dark, and lose it by degrees.

It appears that all bodies, without exception, become red or luminous, when saturated with lumic. Metal, charcoal, earths, nay even liquids, to which you apply a heat superior to that which is necessary for the fusion of the first, and the combustion or volatisation of the others, all exhibit a red colour. It would seem that, in this case, the caloric and lumic, being no longer able to combine with the bodies which are saturated with it, become free or *radiating*.

From all the facts with which we are acquainted, the existence of lumic appears to be inseparable from that of caloric: for the action of caloric constantly produces light; and when the light is itself collected in the focus of lenses, or reflected in that of concave mirrors, it produces all the effects of accumulated caloric. We may be permitted to add, that, among coloured bodies those which best absorb lumic, are also the hottest; and that, in any given case, the stronger the light is, so much the more intense is the heat. Scheele observed, that if you expose to the sun two thermometers in every respect alike, except that one shall be filled with coloured, and the other with unco-

loured alcohol, the latter will rise more slowly than the other; but if you put the two thermometers in cold water, or in the dark, the variations of the two liquids are perfectly alike.

Caloric and lumic uniformly concur in producing the same effects; they are blended together in many phenomena, and appear to be identically the same. But they differ in this point, that caloric seems more easy to be absorbed than lumic: for example, glasses and transparent liquids do not give a passage to radiating caloric, though, at the same time, they suffer lumic to pass through them. It appears, therefore, that caloric possesses in a less degree the qualities of eminent elasticity; nay it is even probable that it is endued with less velocity.

There are certain chemical effects, in which heat and light appear to act in a different manner. Light, for example, disengages oxygen gas from nitric acid, whereas heat disengages nitrous gas. Oxygenated muriatic acid parts with its oxygen in the light; but it may be distilled by heat without decomposition. M. Berthollet, who is inclined to consider caloric and lumic as one and the same substance, dif-

fering only in the state in which it happens to be, has collected all the facts which would seem to establish a difference of nature between these two fluids, for the purpose of drawing from all their results this conclusion, that there is no difference except in the energy of action. We shall also collect a few phenomena, in order to throw some light on this subject.

Count Rumford impregnated white silk, linen and cotton cloth, and white magnesia, with a solution of gold. Those substances, exposed to the sun or the light of a candle, assumed a beautiful purple colour; in the dark they underwent no change whatever.

Scheele observed, that muriate of silver, covered with water, and exposed to the sun, emitted muriatic acid. M. Berthollet satisfied himself that the bubbles exhaled from it were nothing but the air adhering to the muriate, and that the water became acid. He exposed the muriate, turned black by the light, to the action of heat in a small retort: it melted, and muriatic acid was disengaged. Light and heat produce, therefore, the same effect on muriate of silver.

Count Rumford exposed to the light of the

sun a bottle containing pieces of charcoal and a solution of gold: the gold was soon reduced; and a solution of silver experienced a similar reduction. The same effect is produced by putting the solutions into tin cylinders, and exposing them to the heat of boiling water.

M. Berthollet repeated the experiment, for the purpose of ascertaining the nature of the gases which are disengaged; and he obtained a mixture of nitrous gas and carbonic acid. He likewise exposed nitric acid, into which he put pieces of charcoal, to the action of light and of boiling water; in either case nitrous gas and carbonic acid were disengaged.

Solutions of gold and silver, mixed with oil of turpentine and olive oil, are alike reduced by the action of light and by that of heat. In this case, the oil becomes black, because they lose their hydrogen.

In the preceding experiments, the effects of caloric and of lumic are the same; there is no difference whatever except in their intensity.

M. Berthollet also endeavours to reconcile with the same principle the disengagement of oxygen gas from oxygenated muriatic acid, and from nitric acid, which is effected by the light,

and not by heat. That difference he ascribes to this circumstance: that, when the acids are engaged in one base, they are capable of supporting a great degree of heat, and of then yielding oxygen gas, which they never do in the state of acids. Hence he concludes, that the difference of action in this case, is also owing to the intensity of action, and supposes no other difference. Here the lumic combines only with the oxygen, whereas the caloric acts upon all the principles, and tends to volatilize them, while one opposes no stronger resistance than the other to its action.

SECTION V.

Of the Modifications produced in Chemical Action by the Pressure of the Atmosphere.

The atmosphere presses upon all bodies; and as this force is constant, it may be considered as a cause which contributes to give each body the constitution that is adapted to it, and which incessantly modifies the efforts of elasticity, and the action of caloric.

The power of pressure exerted by the atmosphere, is equal to the weight of a column of mercury of twenty-eight inches, or of a column of water of thirty-two feet; for it is able to raise those two liquids to that height, and to keep them there in equilibrium.

In examining the effects of the compression of the atmosphere, Lavoisier remarks, that were it not for this, the particles of liquids would wander at large without any thing to keep them together except their own gravity, which would collect them for the purpose of forming an atmosphere.

Mr. Dalton disputes the truth of the assertion, that the pressure of the atmosphere keeps water in a liquid state. He observes, that were the weight of the atmosphere to be instantly removed, the aqueous portion which exists in it would not be much increased, because, as he says, it is nearly at the *maximum* which the temperature is capable of producing and maintaining. The removal of the obstacle would, in his opinion, accelerate the evaporation, without very sensibly augmenting the absolute quantity. Mr. Dalton seems to confound the soluble quantity of water in the atmosphere,

with that which, when reduced to vapour, would of itself alone form an atmosphere.

When we observe that, by a slight diminution in the pressure of the atmosphere, produced either by the air-pump, or by ascending to the most elevated points of the globe, we convert ether and alcohol into vapour, and facilitate the ebullition of all kinds of liquids, &c. we cannot deny that, if the atmosphere ceased to press upon the globe, it would be replaced by the vaporisation of almost all the liquids with which we are acquainted.

By approximating the particles of bodies, the pressure of the atmospheric air increases their affinity. M. Biot has demonstrated the possibility of forming water, by subjecting to a violent pressure a mixture of hydrogen gas in suitable proportions.

SECTION VI.

Of the Modifications produced in Chemical Action by Vitality.

The laws of nature are assuredly constant and immutable; and to this their peculiar

characteristic are owing that uniformity of action, and that succession of phenomena, which renew and perpetuate every thing that exists, without the smallest change in the nature of bodies.

But when several laws exercise their operative power on the same substance, and concur in producing one and the same action, the effect, which belongs exclusively to none of them, must be considered as the result of a common effort, in which each of the acting laws has a part more or less important. It is in this commixture of powers, in this result of action, that we must seek to discover how much belongs to each of the acting laws; the greater is the number of the laws that concur in the action, so much the more difficult of solution the problem becomes.

Let us suppose, for a moment, that the germs of life ceased to act in nature; our planet would exhibit nothing but masses of matter subject to the invariable laws of gravity and affinities. These laws would determine the arrangement of the masses, and the disposition of their respective particles.

But if we survey this scene of action and of

reaction, of composition and of decomposition, which organized beings, both vegetable and animal, present to our view; we shall find new agents concurring to produce the same effect, and to modify, *ad infinitum*, the action of the two primordial laws, of which we have already treated.

Every living body is subject to the vital laws of sensibility, irritability, &c. which regulate its functions, and constitute what in it is denominated *life*: but these laws are not equally numerous, nor are they accompanied with an equal degree of intensity or of energy, in the various classes of organized beings. The more numerous and intense are these vital laws, the more their phenomena disagree with the regular results presented by their affinities when they operate on inanimate matter.

All bodies, without exception, have peculiar affinities, by virtue of which they make choice of certain substances and repel others; but the results of combinations are not alike in all. When an earth or a metal combines with other bodies, it changes its nature, that is, the new compound no longer possesses the characteristics of the elements which compose it; they

are new beings, whose nature is still liable to be changed every moment by the application and combination of new substances. Organic bodies, on the contrary, have the faculty of appropriating and assimilating aliments, without changing their nature: they impress their peculiar character on the substance which serves them for food, and retain their primitive type without the least alteration.

Accordingly, there is a choice of matter and assimilation in organic and living bodies; they invariably retain their primitive form, character, and nature; whereas unorganic bodies are liable to the composition and formation of a new body, whose form and properties cannot be deduced either from the form, or from the properties of the substances of which it is combined.

If we pay close attention to the phenomena and the results of this assimilation in organic bodies, we shall find that the different degrees of intensity in the vital forces are productive of infinite modifications in them. The more intense or energetic are the vital forces, the less powerful is the influence of external agents on the functions of life. In the vegetable, for in-

stance, the principal organs are concealed under the epidermis; they receive, in this position, the immediate action of heat, of the air and of water, as well as the influence of the internal powers of vitality. These organs exist, if I may so express myself, between the organic faculties of the plant, and the very powerful action of external causes. This function, therefore, essentially depends on the combined influence of vital action, and of the action of air, water, heat, and light. The plant cannot digest either in a very cold or in a very hot temperature: it languishes in the dark, and withers in too strong a light. Nevertheless it does not receive in an absolute manner the influence or necessary effect of these agents: it has a temperature adapted to it; it decomposes the water which wets it; it preserves and perpetuates its species, and will perish rather than make choice of and assimilate deleterious substances with itself.

But how much more energetic is this vitality in animals: nature has placed their principal organs in the very centre of their bodies, for the purpose of skreening them from the action of external causes. Here all is vital; and the

variations of temperature, air, and water, have scarcely any influence on the results.

In unorganic bodies, therefore, there is nothing but matter and affinity; all the changes which take place in them proceed from external causes; the air, water, heat, produce in them effects necessary, constant and invariable.

In organic bodies, besides matter and affinity, there are vital laws which are incessantly modifying the action of external agents, and that of affinity.

A view of the effect produced by air, water, and heat, when they act either on a living body, or on the same body when dead, will be sufficient to convince us of the extraordinary power of vitality. We shall perceive that the air and water are subservient to the respiration and nourishment of the living animal, by the decomposition which they undergo in its organs, at the same time that heat animates and vivifies all their springs. But after the death of the organic being, these same bodies become the first agents of its decomposition, because, in order to preserve it without alteration, it should be protected from their action. The root of a living plant, plunged into water, de-

composes that liquid, and derives nourishment from it; but the same root, when dead, and put into water, is in its turn decomposed.

No other proofs are necessary, in my opinion, to produce the conviction of this great truth, that the phenomena and the results proceeding from the action of air, water, and caloric, on organized bodies, are essentially different, according as those bodies are dead or alive.

We may therefore conclude, that vitality modifies the law of affinities in the living body; or rather, that the action of vitality concurs with that of affinity to produce effects which are common to both.

From this incontestible principle it follows, that vitality renders the application of the chemical laws, deduced from the affinity of dead bodies, the more difficult, in proportion as the living body is endowed with more numerous, or more energetic vital faculties.

In descending from the best organized being to inanimate matter, we find the influence of vitality successively decreasing, and the power of affinity gradually resuming its empire.

We must, not, however, by any means con-

clude, that the law of affinities between the particles of animated matter differs from the law of affinity between the particles of inanimate matter. The law is alike in both cases, and affinity is the same with respect to bodies of every description: but it produces constant and invariable effects, when it is to act alone on inanimate matter; whereas, in living bodies, its action is modified by that of the vital laws.

The laws of vitality not only modify the results of the law of affinities in a particular and different manner in every class of living beings; but they likewise diversify its effects in the individuals of the same species, and frequently in the same individual, according to its affections, maladies, dispositions, and many other causes which present themselves. We must not, therefore, be surprised, if we find a very great variation in the results of experiments made on living bodies by men equally worthy of credit, and if the observations on vegetation present very different phenomena.

The chemistry of living bodies requires a particular and perfectly distinct study; chemistry alone being incapable of explaining

any of its functions. We are acquainted, it is true, with the effects of air, water, and heat, on inanimate matter; but the observation of the phenomena of living bodies can alone teach us the modifications caused by vitality in all these results.

We should consequently involve ourselves in an egregious error, were we to imagine it to be possible to apply and transfer to living bodies the results of action which we observe in dead bodies. Animal chemistry has its peculiar laws, and presents to us results that can neither be foreseen nor accounted for, consistently with the laws of affinity, which we study in inanimate matter. This truth was so deeply impressed on the minds of Stahl and Boerhaave, who, to an intimate acquaintance with chemistry, united a most extensive knowledge of the animal economy, that they abstained from any application of chemistry to the phenomena of the human body; and that the former became the founder of the sect of the *Animists*, and the latter of that of the *Mecanicians*.

For my own part, however, I am far from thinking, that a proficiency in chemistry is either useless or foreign to the study of the

phenomena exhibited by the living body. Chemistry instructs us in the nature and the properties of all the bodies that act on the animal economy; it indicates the alterations they experience in their action; it even furnishes us with the means of discovering and appreciating many changes which take place in the living body. Thus, for example, on analysing the air before and after respiration, we may convince ourselves that a portion of this fluid is absorbed, from which circumstance has been deduced the conclusion, that there is a constant production of heat in the lungs. These chemical facts, which are confirmed by physiological observation, establish this truth in an incontestible manner. But every thing that is essentially connected with vitality, all that comprises the functions more particularly dependent on life, such as chilification, sanguification, the secretion of humours, nutrition, digestion, the choice of aliments, the effect of medicines, the action of the organs, can neither be explained nor elucidated by chemistry alone.

What we have here advanced must necessarily lead to this conclusion, that to acquire

an accurate knowledge of the functions of the animal economy, it is necessary to combine the analysis of the chemist with the observation of the physiologist. The former makes us acquainted with the materials on which the vital action is exercised; it determines their primitive nature, and shews their alterations; it completes, I may say, the labours of the anatomist, by analysing the organs and the humors which the latter had only separated and described. But there end his functions, there are the limits of his power: for hitherto we have operated only on rude matter; the analysis and the dissection have been exercised only on an inanimate body; and we have still to prosecute the study of the phenomena, which constitute life in organic bodies. Here observation alone ought to be taken for our guide, because the principle which animates their every particle cannot be subjected either to chemical analysis, or to the operations of the knife. This study is the more difficult, because, if we torture the living body by any means whatever, we cause it to depart from its natural state; and this being the case, it presents to us nothing but alterations. This study is the more difficult, because

SECTION I.

Of the Mechanical Operations employed by the Chemist, to prepare the Particles of Bodies for Chemical Action.

When the chemist intends to operate upon a solid body, he first reduces it into an infinite number of smaller bodies, and this division is effected by the hammer, the file, the press, the chisel, or the pestle.

He employs one or other of these agents, according to the nature of the body which is the subject of the analysis.

He uses the hammer to break stones; the rasp to divide and pull to pieces roots, fruits, or fresh bark; the knife and chisel to cut in slices animal substances, and vegetable matters; the press to squeeze out the juices of vegetable, or the fluids of animal parts.

In a laboratory a pestle and mortar are most commonly used, because, exclusive of the advantage it affords of conveniently triturating and pounding hard substances, the form of the

mortar prevents any portion of them from being lost.

The nature of the substances which he has occasion to pound, in order to prepare them for analysis, obliges the chemist to provide mortars and pestles of different qualities for his laboratory.

He must have glass mortars for all corrosive substances, which are not very hard; mortars of stone, marble, agate, and porphyry, for the trituration of solid bodies, or to bruise herbs, to reduce woods, to pound fruits, and to prepare them to receive the action of the press; mortars of gun-metal, iron, or brass, for all the operations that are performed on such bodies as oppose a resistance to the action of the pestle. The nature of the body must direct him in the choice of one mortar in preference to another; and, in this respect, he ought to consult their hardness and their action, that the mortar may resist and not mingle any of its principles with those of the substance he is about to analyse.

It is scarcely necessary to observe, that, in order that the matter may be properly subjected to the effort of the pestle, the bottom of the mortar must be of a concave form, and so

adapted to the convex figure of the pestle, that they be in contact in every point.

The chemist who should merely employ the equal and perpendicular descent of the pestle to effect trituration, would obtain a very imperfect and unequal division: one part of the matter would necessarily escape pulverization; whereas by rolling and turning about the head of the pestle upon the matter, he presses it forcibly against the sides, and successively brings under the action of the pestle, all those particles which might otherwise have escaped the collision.

It frequently happens, that the rapid motion of the pestle causes part of the matter to fly off in dust. To obviate this accident, which very frequently produces exhalations, pernicious to health, and, which, at all events, are attended with some loss of matter, the mortar is covered with a piece of linen cloth, in the middle of which a hole is made to remit the pestle. By this expedient you may prevent all evaporation; but the same end may likewise be answered by moistening the substance, when it can be done without inconvenience.

There are bodies which it would be very dif-

ficult to pound, were we not to take the precaution to facilitate the process by certain preliminary preparations; for example, almost all stones that are intended for trituration are heated to a red heat, and in that state they are thrown into water for the purpose of cooling them. By this method they are rendered extremely brittle, and may afterwards be broken with ease.

There are metals, such as zinc, which yield under the hammer without breaking; but if zinc be heated, it then breaks with the slightest effort.

When the substance is brought by trituration, to a certain degree of division, you separate with the sieve all that is sufficiently pounded, and throw back into the mortar whatever requires a farther degree of pulverization.

By sifting you accelerate the operation, because it is nothing but the fine dust that surrounds the unpounded particles, which causes them to escape the action of the pestle.

As the sifting occasions a volatilization of an extremely subtle portion of the matter, the respiration of which might be pernicious, this inconvenience is obviated by employing a sieve

composed of three parts, tha is, of the sieve itself, a cover and a receptacle underneath. In this case, you put the matter into the sieve, to which you then affix the receptacle and the cover, and proceed to the operation. The powder passes through the sieve into the receptacle, out of which it is taken when the operation is finished.

By adapting to each other several sieves, the holes of which are of different dimensions, and by placing them over one another, in such a manner, that the sieve with the largest holes shall be uppermost, and that with the smallest holes lowermost, you may obtain, by one and the same operation, several products of different sizes. It is in this manner that the different kinds of shot for the sportsman are separated.

Another operation performed by means of water may be substituted for that of sifting. The pounded matters need only to be shaken in that liquid; they immediately settle at different heights, according to their division, because the largest precipitate themselves first. This process is employed in the arts to obtain certain preparations at various degrees of fineness. As they are generally broken by the aid

of millstones which move in large tubs full of water, the motion of the stone agitates the particles, the lightest of which ascend to the top of the tub, while the coarsest remain under the stone. By turning cocks, fixed at different heights, and drawing off the liquid that is above them, all the degrees of fineness that are required may be obtained.

In some other operations of the arts a current of water is made to pass over the matter subjected to the action of the pestle: this water successively carries away all that is sufficiently divided to be removed. It runs into a series of reservoirs, where it deposits, more or less speedily, what it has carried away; so that the first reservoirs retain the coarsest matter, being the heaviest, and the last receives only the finest and most subtle portion.

Washing is employed, not only to separate homogenous matters, differing only in their degree of division; but it likewise affords the means of separating matters of the same degree of fineness, and of different specific gravity. It is more particularly in the operations of the mines that these methods are employed for the

purpose of separating the ore, or the metals, from the stones with which they are united.

Porphyrisation is nothing but a more complete trituration. It is performed on a flat piece of porphyry, or any other stone that is very hard, and has a very smooth surface, with the aid of a stone of the same degree of hardness, which is called a *mullar*. The matter is spread out upon the slab of porphyry; you then take the mullar with both hands, and work it circularly, and in different directions, to grind the matter. That part of the mullar which comes in contact with the porphyry, must not be perfectly flat; its surface should be a portion of a sphere with a very large radius; otherwise the matter would be driven before the mullar, and could not get underneath it to be ground. When the matter is too much spread on the surface of the porphyry, it may be brought back to the centre, by means of a knife with a very thin blade of iron, horn, or ivory.

Before the chemist begins to operate chemically upon any substance, he determines its weight; and the means he employs belong to

the series of operations preparatory to chemical action.

Whenever he wishes to determine the quantity of matter which a body contains, he balances it against other bodies whose weight he knows, and which he takes for the term of comparison.

The instrument which is most commonly used is an iron lever, suspended by the middle, so that the two arms shall be suspended in equilibrium, and possess the power of a free ascent or descent, with as little friction as possible. These instruments are termed *balances*, or *scales*.

But in the various circumstances in which the chemist has occasion to determine the weight of bodies, two objects present themselves. The first is, to determine the weight of a mass, and the second, to compare the respective weight of a given volume of that mass, with a like volume of other known bodies. In the first case it is the *absolute weight*, and in the second the *specific weight*, that is sought.

When he is about to determine the absolute weight, he has either to weigh large volumes,

or small objects; and employs large or small scales accordingly.

A laboratory should be provided with scales of extreme precision; for as the chemist operates there only on small masses, and as he frequently extracts, by analysis, some atoms whose weight it is always of consequence to appreciate, he ought to be provided with instruments of extreme nicety for that purpose. Besides, it is almost always on the results of analyses that we decide either to work a mine, or to engage in other important undertakings: so that it must be evident of what consequence it is to avoid every cause of error.

As there is often occasion in laboratories to weigh salts, acids, and other corrosive matters, the chemist is obliged to put them up in glass vessels; and it is then indispensably necessary to weigh separately the vessel that contains them, to deduct that weight from the total weight, which leaves that of the liquid. This double operation is attended with a great loss of time; and I obviate this inconvenience, by using two glass capsules of the same weight, moveable and deep, which are placed in the

two basins of a pair of scales, and which may be taken out at pleasure.

The scales should hang in a dry place, in a good light, and out of the reach of the corrosive vapours of the laboratory. Without this precaution they grow rusty, and become spoiled. The most delicate should be kept in glass cases, and should not be taken out without occasion.

If the chemist has to weigh gases, it is obvious that it will be necessary to make certain modifications in the processes above described. And as he is obliged to inclose in vessels the liquids whose weight he wishes to know, so he is also necessitated to shut up aeriform substances. For this purpose he has a large globe, containing at least one cubic foot, that is, seventeen or eighteen quarts. This is affixed to the plate of the air-pump, and it is emptied as much as possible, the operator taking care to observe the height to which the barometer gage descends. When empty, the cock affixed to the covering of the neck is shut, and the globe is weighed with the most scrupulous accuracy. It is then screwed on a bell which contains the gas that is to be weighed, and which stands on the table

of the hydropneumatic tub. It is sufficient to open the cock in order to determine the ascension of the gas into the receiver; it is necessary to plunge the bell into the tub, so that the water on the outside may be on a level with that which is within. The cock is then shut, the globe unscrewed, and again weighed. The weight, deducting that of the empty globe, gives the gravity of the volume of gas which it contains. Multiply the weight by 1728, and divide the product by the number of cubic inches equal to the capacity of the balloon, and you have the weight of a cubic foot of the gas which is the subject of the experiment. To reduce the weight of the cubic foot to that which the same gas would have under a pressure of twenty-eight inches of mercury, and at a temperature of ten degrees of the thermometer, employ the process detailed by Lavoisier in his *Elements of Chemistry*.

You must by no means neglect to take into account the small portion of air left in the globe; it is estimated according to the height at which the barometer gage stood. If that height was, for instance, $\frac{1}{100}$ of the total height of the barometer, you may conclude that $\frac{1}{100}$

part of air remained in the globe, and that the total volume of gas was no more than $\frac{33}{100}$ of the total volume of the globe.

On these principles Lavoisier drew up the following table of the weights of different gases, at a pressure of twenty-eight inches, and at ten degrees of the thermometer.

Names of gases.	Weight of a cubic inch.	Weight of a cubic foot.			Names of authors who ascertained the weights.
	Grains.	oz.	dwt.	gr.	
Atmospheric air	0,46005	1	3	3,00	Lavoisier.
Azotic gas	0,44444	1	2	48,00	Lavoisier.
Oxygen gas	0,50694	1	4	12,00	Lavoisier.
Hydrogen gas	0,03539	0	0	61,15	Lavoisier.
Carbonic acid gas	0,68983	2	0	40,00	Lavoisier.
Nitrous gas	0,54690	1	5	9,14	Kirwan.
Ammoniacal gas	0,27488	0	6	43,00	Kirwan.
Sulphurous acid gas	1,03820	3	0	66,00	Kirwan.

By *specific gravity* is meant the absolute weight of bodies divided by their volume; or, what amounts to the same thing, the weight which any given volume of a body weighs. But, in order to have a term of comparison,

the weight of which shall be invariable, and which, consequently, may be taken for the unit to which the weight of the substance that is the subject of the experiment is referred; distilled water has been chosen as the body whose gravity, when of the same volume, is not liable to variation. Thus the weight of the water being represented by the number 1, the weight of an equal volume of gold will be represented by 19.

In areometry, therefore, the whole business consists in obtaining the gravity of a body compared to that of a similar volume of distilled water. The methods vary according to the constitution of bodies.

To find the weight of a solid, insoluble in water, it is weighed first in the air, and then in water. By deducting from the total weight what it has lost in the water, you have its gravity compared to that of an equal volume of water. This process is grounded on the two following principles.

1. That a body plunged and immersed in a liquid displaces a volume of water equal to its own.

2. That the weight of the water displaced is equal to that which the body loses in its immersion.

When solids are lighter than water, we employ for the purpose of immersing them, a body whose gravity in water is already known, and which we deduct when we determine, by calculation, the comparative weight of the solid.

The simplest instrument for weighing solids is a balance, from one arm of which the substance is suspended by a very fine thread. You first weigh the body in the air, and afterwards in water; and deduce, from the difference, the weight of the volume of displaced water to be equal to that of the body.

Mr. Nicholson's scales for solids are the most portable. This instrument consists of a glass or metal cylinder, from the extremity of which is suspended one of the scales. The other is placed at the upper part, and affixed to a very small shank. You lay the body to be weighed upon the upper scale, and keep adding weights till it descends to a certain mark. Compare these weights with those which are required to make the instrument descend to the same mark;

and the difference gives the absolute weight of the body. Then place the body to be weighed in the lower scale; charge the upper with weights till it descends to the mark; and you have the weight of an equal volume of water upon deducting from the total weight that which you have just added.

M. Guyton has improved this instrument by adapting it to the weighing of liquids as well as solids. He has added to it a piece which he calls a *plunger*, because it is designed to be placed in the lower scale. This plunger is a glass ball, ballasted with a sufficient quantity of mercury to render its total weight equal to the constant additional weight, and likewise to the weight of the volume of water which this plunger displaces.

When you have occasion to weigh liquids of less specific gravity than water, you know the weight of the instrument in water, which you compare with its weight in the lightest liquid.

In the case of a very heavy liquid, besides the plunger, you put weights into the upper scale to sink it down to the mark.

It is unnecessary to observe that this instru-

ment can only weigh such bodies whose weight does not exceed the additional weight necessary for sinking the gravimeter to the mark.

Various instruments, more or less proper for determining the comparative gravity of liquids, have been at different times proposed.

1. Weigh an empty bottle; fill it with distilled water, and weigh it again; pour out the water, and replace it with an equal volume of the liquid whose comparative gravity you wish to ascertain; if you deduct in both cases the weight of the bottle, it is evident that you will have the comparative weight of the two liquids. This is Homberg's process.

2. Plunge into distilled water a body which is unassailable by that liquid; load the body with different weights to sink it to a fixed and determinate mark on a standard to which it is affixed. Knowing the weight of the instrument, and those which were required to depress it, their sum gives the weight of the water displaced. Plunge the same instrument into the liquid whose gravity you wish to ascertain; charge it with weights, to sink it to the same mark, and the sum total of the gravity of the instrument, and of the added weights, gives

the weight of the liquid displaced. This weight compared to that of an equal volume of displaced water, forms the comparative gravity. This is Fahrenheit's areometer.

3. The simplest instrument for weighing liquids, or determining their degree of concentration, is Baume's areometer. It consists of a graduated glass tube, ballasted at the lower end by a small quantity of mercury, which keeps it continually in a vertical position. When plunged into distilled water, it stops at the point marked zero: the upper graduations express the different degrees to which it sinks in the lightest liquids; the lower mark the degrees to which it rises in the heaviest liquids. This instrument is convenient for use; and though it does not present a mathematical precision, it serves for the ordinary purposes of our manufactures, in which scarcely any other is employed.

4. Mr. Ramsden proposed a very small pair of brass scales with unequal levers, with a weight running on one of them after the manner of the Roman steel-yard. At the end of the other arm is a fine cord of horse-hair, from which is suspended a glass ball ballasted with

mercury. The gravity of liquids is estimated by the weight which the ball gives when it is immersed. Instead of the hair-cord it is adviseable to use wire of platina.*

It is scarcely necessary to observe, that in order to appreciate the specific gravity of fluids with great precision, it is necessary to take account of the temperature of the atmosphere, which, by dilating them more or less, produces a variation in the instruments. Those, however, which we have described above, are sufficient for ordinary purposes; and it is unnecessary to estimate the temperature, except in regard to the most evaporable liquors, or those in which the smallest difference in consistency is productive of great variations in commerce. Hence it is that in the sale of ardent spirits and alcohol it has become customary to calculate the degree by the application of the thermometer and areometer. In the Memoirs of the Society of Sciences of Montpelier may be

* On this subject consult the *Memoirs of M. Hassenfratz, Chemical Essays on Areometry*, and *Brisson on Specific Gravities.*

found a series of ingenious experiments on the mixtures of water and alcohol, and on the dilatability of those mixtures at various degrees of temperature. In conformity with the results of these experiments was constructed the spirit-gage employed in the south of France to determine the degrees of strength of ardent spirits, which is accompanied with the corrections adapted to different degrees of temperature.

SECTION II.

Of Solution considered as a Medium preparatory to Chemical Action.

We call *solution* the division and disappearance of any kind of body in a liquid, without either of them undergoing any alteration in its nature.

We adopt this term in the sense given to it by the celebrated Lavoisier,* and with the

* Elementary Treatise on Chemistry, vol. ii. chap. 5, sect. 1.

greater justice, as that operation is essentially different from dissolution, which ought to be employed only to explain the action of an acid on a metal, an earth, or an alkali. In the latter case, there is not only a solution, but likewise a combination, and sometimes a decomposition of one of the bodies, as when an acid is made to act on a metal, or on a neutral salt, the acid of which may be displaced by the more powerful acid which is employed.*

From this distinction between solution and dissolution, established by Lavoisier, it follows, that the term *dissolvent* cannot be applied to the liquid which determines the solution; in-

* As this chapter treats only of an operation preparatory to chemical action, it is obvious that it would not be proper to consider, in this place, the dissolution which is attended with *combination* or *decomposition*. It cannot but excite astonishment that as the results of *solution* and *dissolution* are so different, those operations should have been expressed, down to the time of Lavoisier by one and the same word. In the language of the sciences, in particular, we should be careful not to apply the same denomination to opposite results or operations totally distinct from each other.

stead of it we must necessarily substitute the word *resolvent*. Thus the resolving body is the liquid in which the body that is resolved disappears; and to express ourselves in a more general manner, we shall say with M. Monges, that the resolvent is the body which preserves its form, and gives it to another.

There are bodies whose constitution is such that they constantly appear in a liquid state, at the ordinary temperature of the atmosphere: in this class we place the *resolvents*, such as water, alcohol, caloric.

Bodies naturally solid or gaseous may be reduced to a liquid state, if we increase the quantity of caloric in the first, or diminish it in the second. Their power of cohesion and elasticity determine the quantity of caloric which must be added or subtracted to produce that effect.

If certain solid and fluid bodies have hitherto withstood solution, the reason is, because we have not been able to apply to the one, and take away from the other, the quantity of caloric necessary to break their cohesion.

When the force of cohesion cannot be over-

come by the affinity of the resolvent, the chemist employs three methods of preparing the body for its solution.

1. He weakens the power of cohesion by mechanical means.

2. He increases the affinity of the resolvent by the concurrence of caloric.

3. He diminishes the cohesion by saturating a portion of its energy by the addition of another body.

The division of a body is attended with the twofold advantage of diminishing the cohesion and of multiplying the surfaces; it weakens the resistance and increases the action. Limestone and quartz, naturally insoluble in water, may be reduced to such a degree of tenacity, as to be carried away by that liquid and slowly deposited; on which their particles reuniting assume regular forms. In this manner we may account for the formation of rock-crystals and calcareous spar on rocky surfaces continually wetted by water which has run through rocks of a nature analogous to that of the crystals.

Bergmann observed, that bodies which are not sensibly attacked when they are in a mass, become soluble when they are divided.

The action of affinity may be further assisted by means of caloric. It has the two-fold advantage of diminishing the cohesion, and of being itself a resolving body; so that whenever caloric is employed in conjunction with another fluid, a complicated effect is obtained from the action of the two agents; and, in order to form a correct idea of the share which caloric has in the result, we ought to consider it in the two points of view under which we have just exhibited it. 1. It weakens the force of cohesion by separating the particles; this effect is sufficient to determine the action of the resolvent in many cases, and contributes to accelerate it in all. 2. It dissolves of itself a part of the body, in proportion to the quantity in which it is employed; refrigeration alone, or what amounts to the same thing, the subtraction of this cause of solution, occasions the precipitation of all that portion of the body which owed its solution only to the caloric.

It must not, however, be imagined, that caloric, in every case, facilitates solutions. This property of caloric is incontestible only when it acts on fixed bodies, whether solid or liquid; for when you operate on bodies whose

natural state is that of an aëriform fluid, the caloric then facilitates the action of that power of elasticity, which is incessantly tending either to reduce those fluids to the state of gas, if they be in combination; or to keep them in that state if they possess their natural expansion; so that in all these cases, caloric tends to develope and to strengthen the energy of elasticity, which is incessantly counterbalancing that of affinities, and resisting the action of resolvents and of dissolvents.

A third method, which is employed to prepare bodies for solution, consists in diminishing the force of cohesion by the combination of another substance. An example will render this perfectly intelligible. When you throw quick-lime into water, the lime attracts and absorbs it; but as it becomes saturated, its force of cohesion decreases, so that, at length, the affinity of the water prevails, and it dissolves a small portion of lime.

Sometimes there is so little affinity between a liquid and a solid, that the latter is not sensibly wetted by the former, and that the liquid stands in large round drops upon its surface. Of this water and tallow afford an example.

Sometimes, on the other hand, the affinity of the resolvent so completely overcomes the resistance of cohesion opposed by the body to be resolved, that it is impossible to preserve to the latter its solid form, except by removing it from the contact with the resolvent. It is this facility, this tendency to solution, which constitutes the character of the class of salts denominated *deliquescent*; because, when they are exposed to the air, they draw from it the small portion of humidity requisite for their solutions.

Dr. Watson, who has most attentively observed the phenomena of solution, has deduced from his numerous experiments these conclusions:

1. That water acquires volume at the moment of the immersion of a salt.

2. That its volume decreases during the dissolution.

3. That it ascends, after the dissolution, higher than its original level.

The first phenomenon is the necessary effect of the immersion of a solid in a liquid.

The second is the immediate result of the lowering of the temperature produced by the solution.

The third indicates that the liquid, on recovering its temperature, is restored to its natural state, with a sensible augmentation of volume, in proportion to the volume of the body with which it is charged. Nevertheless the augmentation of volume bears no proportion to that of the body resolved, which announces a kind of penetration, or of combination between the two bodies.

The operation of the solution of salts in water invariably produces cold. Messrs. Fourcroy and Vauquelin have, it is true, instructed us, that when the water of crystallization is separted from the salts which require a great quantity in order to crystallize, their solution in water is attended with a disengagement of caloric; but then those salts are no longer in their natural state; and they produce cold, like all the others, when they are resolved with all their water of crystallization.

When the water holds a salt in dissolution, the new body may then be considered as having particular affinities, distinct from those of the two bodies which compose it. Thus the solution of alum in water, parts with a large portion of alumine, which precipitates as soon as the alum of crystallization is disengaged.

When a liquid holds several salts in solution, evaporation or lowering of the temperature precipitates them in an inverse ratio to their affinities with the resolvent. These salts are seldom separated perfectly pure, because they exercise mutual affinities, by virtue of which they unite and commix more or less. Two liquids are likewise subject to be resolved when their respective affinities are stronger than their powers of cohesion. If water and ether be mixed in equal parts, they form two liquids which remain separate; the one below, composed of much water and little ether; the other above, consisting of a small proportion of water and a large quantity of ether.

Solution may be accelerated by slightly agitating the liquid; for, by this expedient, the water, whose affinity is weakened, is successively displaced, and makes room for a more eager portion of the same liquid. The motion has likewise the advantage of producing on the surface of the body that is intended to be resolved, a mechanical friction, which detaches some of its particles, and gives them up to the action of the resolvent.

As it is of consequence in many of the arts,

that liquids should not evaporate till they are nearly saturated with the body that is operated upon, the same liquid is passed, at several times, over fresh quantities of the body to be resolved, and is charged with it till it arrives at the requisite degree of concentration. The same result is obtained by causing the liquid to pass through a very thick bed of the body which it is intended to resolve, and leaving the two bodies in contact long enough to produce saturation.

SECTION III.

Of Crystallization considered as a Medium preparatory to Chemical Action.

The object of almost all solutions and evaporations is to concentrate liquids, in order to effect the crystallization of the salts which are dissolved. The particles which are thus concentrated have a continual tendency to assume polyhedral, constant and determinate forms.

The regularity of the forms is a law of matter as general as that of gravity.

Nature has impressed on every class of bodies an invariable form, and it is this variation in

form that draws the principal line of demarcation between them, and that enables us to distinguish them at the first sight.

It is this property, possessed by all bodies, of affecting an invariable form, that chemists have termed *crystallization*.

In organic beings the form appears to be most generally adapted to the wants of the living body; but in mineral substances it seems to be a matter of indifference.

The first chemists who discovered that the figures of bodies were almost invariably the same, denominated crystals after the resemblance more or less rude, which they thought they perceived between them and known bodies; hence the name of crystals in the form of tombs, diamonds, crosses, knife blades, &c.

These expressions, which referred only to bodies whose figures are extremely variable, conveyed but very confused ideas to the mind. The celebrated Linnæus appears to have been the first who ascertained that all these forms were geometrical; this led him to imagine, that he might make it the basis of the methodical distribution, or classification of mineral substances.

Romé de Lisle submitted all the known forms to a strict examination, and was of opinion that he could discover, in the great variety of figures presented by the crystals of the same species of body, a primitive form, of which the others were but modifications.

By dividing crystals by mechanical means, M. Haüy has demonstrated the existence of a primitive nucleus in each crystal. This nucleus has an invariable and determinate form for each kind of body, but the successive application of new lamina produces infinite modifications in it. That celebrated mineralogist has shewn in what manner these lamina, superadded to the primitive form, are capable, by their decrease, of varying, modifying, and changing it. His works leave nothing but the impression of truth on the minds of all those who are seriously engaged in the study of crystallography.

Accordingly, by dividing an hexahedral prism of calcareous spar by sections parallel to each other, you may remove, successively, all the lamina in which it is enveloped, till you come to an invariably uniform nucleus, which represents a perfect rhomboid. By breaking off the

eight solid angles of a cube of fluor spar, you obtain an octahedron. The ponderous spar will produce an upright prism with rhomboidal bases; feld-spar an oblique-angled parallelopipedon; the beryl, an upright hexahedral prism; adamantine spar, a somewhat acute rhomboid; blend, a dodecahedron with rhomboidal surfaces; iron of the island of Alba, a cube, &c.

If, after coming to the last subdivision, you were to attempt to proceed in the same manner in other directions, you would break the crystal instead of dividing it.

But the solid which forms the nucleus may also be subdivided in a direction parallel to its faces. The same is the case with respect to the enveloping matter, which may be divided by sections parallel to the faces of the original crystal; so that the detached parts are similar to each other, differing only in bulk, which keeps diminishing the longer the division is continued. It is these small similar solids, susceptible of an extreme division, that form the integral particles of crystal.

Having ascertained the primitive figure of the crystal, and consequently that of its inte-

gral particles, the next point was to enquire for and determine the laws, according to which these particles arranged themselves, in order to form around this nucleus, a covering which should present polyhedrons very different from each other, though originating from the same substance. Now M. Haüy has demonstrated, that all the parts of this covering are formed of lamina, which decrease regularly by subtractions of one or more ranges of integral particles. Thus, for example, by raising on each face of a primitive cube a series of pyramids, each of which is diminished by a range of small elementary cubes, you will obtain a decahedron; and the cube, before it arrives at that form, will pass through a multitude of intermediate figures; so that, if the work of nature stops at one or the other of these passages, you will have modifications in the primitive form.

As the diminutions are formed by lamina, whose particles are very diminutive, the faces of the pyramid are exceedingly smooth. But if the courses of the pyramid decrease in a greater progression, that is, if instead of a range of cubes, there is a subtraction of from four to six from one course to another, the pyramids

will be more elliptical, and as their adjacent faces can no longer be level, the surface of the secondary solid will be composed of twenty-four isosceles triangles inclined over one another.

The diminutions of the superincumbent lamina take place, in general, in a direction parallel either to the edges of the nucleus, or to the diagonals to the former. M. Haüy has given the appellation of *diminutions on the edges*, and to the latter that of *diminutions on the angles*. There are some rare cases in which these diminutions are mixed.

Sometimes the diminutions take place on all the edges, as in the dodecahedron with rhomboidal sides mentioned above; sometimes in all the angles, as in the octahedron, from which the cube originates; sometimes only on certain sides, or certain angles.

Sometimes the diminutions are uniform, both on the edges and on the angles. At others they vary from one edge to another, or from one angle to another; this happens more particularly when the nucleus has a symmetrical form, and when the faces differ, for example, by their respective inclination, or by the measure of their angles. In certain cases, the di-

minutions on the edges concur with the diminutions on the angles to produce one even crystalline form. It likewise happens, sometimes, that one edge or one angle is subject to several laws of diminution which succeed each other.

The number of subtracted ranges is not, in general, very variable; the subtractions are most frequently formed by one or two ranges of particles, and this decreases the number of forms which might be produced by the diminutions. If there were diminutions by ten, twenty, thirty, or forty ranges, as might be possible, the prodigious variety of forms would be sufficient to startle the imagination. But notwithstanding the narrow limits by which the laws of crystallization are bounded, M. Haüy has found, by confining himself to the two most simple laws, that is, to those which produce the subtractions by one or two ranges, that calcareous spar is susceptible of 240,000 different forms, and of 8,388,604, admitting diminutions by three and four ranges.

The stripes or grooves which appear on the surface of most crystals are always parallel to the borders of the superincumbent lamina.

These points, or these inequalities in the work of crystallization, announce that nature has not been in full possession of the conditions necessary for perfecting her operation; but these apparent anomalies become a new proof of the diminution of the lamina.

The fecundity of the laws upon which depend the variations of crystalline forms is so great, that frequently particles of various figures arrange themselves in such a manner as to form similar polyhedrons in different kinds of minerals. Thus the dodecahedron, with rhomboidal sides, which may be obtained by combining cubic particles, proceeds in the garnet from small tetrahedrons with isosceles-triangular faces. It is likewise possible, that similar particles may produce the same crystalline form by different laws of diminution; and there may exist, by virtue of a simple law of diminution, a crystal which may externally resemble the nucleus, that is, a solid resulting from none of the laws of diminution.

M. Haüy has reduced to six primitive forms all those which mechanical analysis presented to him in the dissections of crystals. These forms are the parallelopipedon in general,

which comprehends the cube, the rhomboid, and all the solids terminated by six parallel faces two and two; the regular tetrahedron; the hexagonal prism; the dodecahedron with rhomboidal sides, and the dodecahedron with isosceles-triangular sides.

This able crystallographer further observed, that the identical forms which have hitherto been found as nuclei in the different species, belong to those that possess a particular character of perfection and regularity; as the cube, the regular octahedron, the regular tetrahedron, the dodecahedron, with rhomboidal, equal and similar sides. These forms, which belong to different species, may be considered as the limits at which nature arrives by different ways, while each of the figures placed between these limits seems to be confined to one particular species.

It now remains for us to shew what conditions are necessary for bringing a body to a perfect crystallization.

1. A body does not crystallize, unless, by a previous division, the cohesion is broken, and the particles are enabled fully and freely to exercise their reciprocal affinities.

This division may be effected by solution; the solution is operated in water for salts, in caloric for minerals, and in alcohol for resins and certain oils.

2. When a body is dissolved in one or the other of these fluids, the reunion of the particles dissolved is effected by evaporation, or by lowering the temperature of the liquid.

In the cases in which the solution is performed by water or alcohol, evaporate till small crystals are formed at the surface or on the sides; then suspend the operation, and as the liquid cools, a great quantity of salt in crystals is precipitated. By evaporating the liquid which remains, after removing the crystals on the top, you may obtain a second quantity of crystals, and extract the liquid from all the salt by successive operations. But if the dissolution is effected by caloric alone, as in metallic fusions, and those of sulphur and phosphorus, other precautions are necessary to decide the crystallization. If you suffer a melted metal to cool, it will not fail to appear again, in consequence of the refrigeration, with its primitive form, exhibiting, at the same time, some confused traces, or imperfect lineaments

of crystallization, such as are observed in antimony and zinc. But if, at the moment when the melted metal begins to harden, you pierce the crust, and let out the metallic liquid contained within, the vacancy will be lined with regular crystals, which almost always present the cubic or octahedral form. Hence we may infer, that the metal in a mass is nothing but an aggregation of crystals, and that the only method of giving it the requisite cohesion and ductility, is to beat it with the hammer, and to *weld* it.

From what has been said concerning crystallization effected by evaporation and refrigeration, we may conclude, that, after having saturated a boiling liquid with any saline substance whatever, nothing more is necessary to obtain a deposit of crystals than to let it cool. We shall easily comprehend all these phenomena, if we consider, that there are then two liquids acting upon the salt (water and caloric); and that, by taking away one of them, we cannot fail of having the whole of the salt which it held in dissolution for a precipitate.

When the evaporation of the dissolvent pro-

ceeds slowly, the crystallization is always more regular; the particles then unite and arrange themselves by virtue of their affinities; but, on the contrary, when the evaporation is rapid, the particles are precipitated upon each other, and there is nothing but confusion in their assemblage.

The slowness of the evaporation not only determines the regularity of the forms, but likewise contributes to give volume to the crystals. This we observe daily in the saline solutions which we leave in a corner of our laboratories; this is demonstrated by all the operations of nature, who forms in time, and by insensible evaporation, saline and stony crystals, which it is impossible for us to imitate, because it is not in our power to cause ages to enter as elements into our operations.

Rest is equally necessary for the liquid, in order to obtain forms of great regularity: uninterrupted agitation prevents all symmetrical arrangement; it precipitates the crystals as fast as they are formed, and you obtain nothing, if I may so express myself, but the integral particles of crystals.

We avail ourselves in the arts of the disturbance produced by agitation in liquids to procure crystals of extreme fineness. It is by this method that we precipitate, in very small and delicate needles, the crystals of sulphate of soda, those of nitrate of potash, &c.

It frequently happens that a dissolution, though complete, refuses to crystallize; in this case a slight agitation of the vessel sometimes decides the crystallization. Fahrenheit observed, that, in this circumstance, heat escaped at the moment of agitation, which seems to prove that the caloric was interposed between the particles, and that nothing but the slightest motion was wanting to disengage it.

A crystal formed in water always retains a more or less considerable portion of the liquid, and this is called the *water of crystallization.*

The only cause of solution is, that the affinity of the liquid overcomes the cohesion which connects the particles of the salt; but in proportion as the mass of the liquid diminishes by evaporation, its affinity of mass decreases, and that of the particles of the body dissolved increases, since they begin to combine with each other. There must consequently be a moment

in which the affinity of the salt overpowers that of the liquid; and from this moment the salt which forms itself into crystals must retain a portion of it. This water of crystallization enters as a principle into the combination, since that liquid cannot be discovered either by the eye, or by the touch, or by hygrometrical tests.

This water of crystallization contributes to give to the crystal its form, transparency, and cohesion. When it is disengaged by heat, these three characters almost always disappear. If, for example, you expose to heat a transparent crystal of sulphate of lime, you will instantly perceive the water to become volatilized and dissipated in vapour; the crystal will lose its transparency, and be rendered friable and pulverulent.

Simple substances, such as metals, certain earths, sulphur, phosphorus, resins, and, in general, all such bodies as are simple, and not soluble in water, crystallize without retaining a sensible quantity of their dissolvent. But compound substances require to be dissolved in a liquid, that they may there acquire the portion necessary for the formation of their crystals.

The water of crystallization is more or less abundant in salts. Mr. Kirwan has determined the quantity in the principal sulphates, nitrates, and muriates, in the following table.

One Hundred Parts.	Acids.	Alkalis.	Earth.	Metals.	Water.
Sulphates of potash	31	63	—	—	6
——— soda	14	22	—	—	64
——— ammoniac	42	40	—	—	18
——— magnesia	24	—	19	—	57
——— alumine	24	—	18	—	58
——— iron	20	—	—	25	55
——— copper	30	—	—	27	43
——— zinc	22	—	—	20	58
Nitrates of potash	30	63	—	—	7
——— soda	29	50	—	—	21
——— ammoniac	46	40	—	—	14
——— lime	33	—	32	—	35
——— magnesia	36	—	27	—	37
Muriates of potash	30	63	—	—	7
——— soda	33	50	—	—	17
——— ammoniac	52	40	—	—	8
——— lime	42	—	38	—	20

There are salts, which, though obtained by evaporation, do not always present themselves with the same quantity of water of crystallization. This was long since observed to be the case with sulphate of soda, which, by the evaporation of the liquid that holds it in solution, partly precipitates itself in a crust which is free from any water of crystallization, while the liquid still keeps back a great quantity of salt in solution. I have had occasion to observe this phenomenon on a large scale in the manufacture of copperas. When the solution of sulphate of iron has arrived at a concentration of thirty-seven or thirty-eight degrees of Baumé's areometer, the liquor becomes white and turbid; a white precipitate is formed, and adheres to the sides of the vessel so closely, that there is some difficulty in separating it from them, which must be done with great care to keep the boilers from melting. This deposit is nothing but sulphate of iron nearly deprived of the water of crystallization. As soon as this deposit is formed, the liquor resumes its greenish colour, and its concentration diminishes five or six degrees. You may concentrate again with-

out injury to thirty-seven or thirty-eight degrees; but, at that point, a new precipitate similar to the first, and accompanied with the same phenomena, is formed. This precipitate does not arrive between the fortieth and forty-second degree till the solution is well saturated, that is, till there is excess of acid. If we examine all the circumstances of this phenomenon, we shall find, that when the solution has nearly reached the thirty-seventh degree, there is then in the liquor only the quantity of water necessary for counter-balancing the affinity of the saline particles; beyond that point the latter prevails, and the salt is precipitated. After this precipitation, the affinity of the water continuing the same, it is, for this reason, superior to that of the remaining salt, and is capable of holding it in solution, till the evaporation, again destroying the equilibrium, produces a new precipitate.

The water of crystallization adheres to salts with more or less force. There are some which suffer it to escape the moment they are exposed to the air, as soda, sulphate of soda, &c. These salts, losing their transparency, their hardness, and their form, become white and fa-

rinaceous, and in this state they are called *flowered salts*. There are others which are not in the smallest degree altered by exposure to the air, and others again which resolve into a liquid as soon as they are exposed to the atmosphere. These are called *deliquescent salts*.

The phenomena presented by the different salts, when forcibly deprived by fire of their water of crystallization, serve to distinguish them. Some decrepitate, others become liquified; these are expanded, and those decomposed, on coals, burning with or without light.

SECTION IV.

Of Caloric considered as a Medium preparatory to Chemical Action.

Of all the means employed by the chemist to prepare bodies for chemical action, none is more active, or of more general use than caloric.

This fluid possesses almost all the properties

that can be wished for: 1. It is capable of combining with certain substances, and causes them to pass over to the permanent state of gaseous or aeriform fluid. 2. It forms with other substances combinations less durable, but yet sufficient to change their constitution from solid to liquid, or from liquid to vapour. 3. In all cases, it separates the particles of bodies, diminishes their cohesion, and facilitates the action of the other substances which are applied to them.

Caloric may, therefore, be considered in two points of view: sometimes as facilitating the action of re-agents, or bodies which are made subservient to the analysis of a substance; sometimes as itself acting in the quality of a re-agent, and taking away from a substance some one of its principles with which it forms a combination; so that caloric sometimes limits its effect to preparing, facilitating, or predisposing to chemical action; and, on the other hand, is itself very often employed as a medium of analysis.

The property which caloric possesses of softening or of melting hard bodies has rendered it

ourselves to an account of the methods it employs in the principal operations, as fusion, distillation, evaporation, and sublimation.

ARTICLE I.

Application of Heat by Means of Furnaces.

The first effect of the calorie applied to bodies is, that it separates their particles without changing their constitution; but the last result of the action of this same fluid is, that it effects their solution. We see caloric act in all these cases in the same manner as water and other liquids act in solutions. Sometimes the solution by caloric renders the body invisible; this is demonstrated by the conversion of various bodies into gas. At others, the bodies lose their solidity, but are not rendered imperceptible to the eye; the disunited particles then roll without sensible solution over one another; and this is the state that is called *fusion*.

Evaporation, distillation, fusion, &c. are almost always operated in *furnaces*, the form of

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which varies according to the nature and quantity of the matter that is to be treated. It varies also according to the kind of combustible that is employed, and the degree of heat that is required.

As furnaces are in very general use in the arts, we think it adviseable to give in this place some general principles relative to their construction, for the purpose of afterwards making a particular application of them to furnaces for fusion, evaporation, and distillation.

SECTION I.

General Principles of the Structure of Furnaces.

A furnace, being intended, from its nature, to contain combustibles, and to concentrate and direct the heat towards the point which is designed to receive it, should be composed of materials which unite the three following conditions.

1. Furnaces should be infusible at the degree of heat which is applied to them.

2. They should neither crack, nor shiver, nor become calcined, nor effloresce.

3. Their materials should be bad conductors of heat.

If it were possible to employ pure earths in the construction of furnaces, we might then possess infusible materials; but nature no where presents them in this state; and they cannot be brought to that degree of purity without laborious and expensive operations Alumine, which can alone serve as a basis for the construction of furnaces, because nothing else possesses the property of hardening in fire, is mixed with lime, magnesia, silic, and iron; and these mixtures are almost all fusible.

Nevertheless, as alumine must form the basis in the construction of furnaces, as no other substance can give them the necessary consistency, we are obliged to make choice out of the class of argils, or clays; and we prefer that kind which seems to unite the properties we want, that is, which does not run at the degree of heat we have occasion to apply.

Before we employ an argil, it is therefore

prudent to make trial of it; which is done by forming it into bricks, and exposing them to a degree of heat at least equal to that which it will be necessary to apply to the furnace to be constructed with it. From the result of this experiment, you may judge not only of its degree of fusibility, but of all the other qualities necessary for a good construction.

The fusibility of argils is not the only defect with which these earthy mixtures may be attended. Alumine has the property of contracting and losing much of its bulk by heat; by whose gradual action, carried to excess, it may be diminished more than half. This contraction of argils is more or less considerable, according to the nature and the proportions of the earths which are mixed with them. It is therefore advisable, also, to ascertain, by positive experiments, the degree of contraction of the earth you design to employ. Potters, sculptors, modellers, brickmakers, are all perfectly acquainted with the contraction of the earths they make use of, and proceed accordingly.

Another defect incident to argils is that of shivering and cracking, in rapidly passing from

one temperature to another. There are few, which, if employed singly in the construction of furnaces, withstand these alternatives: so that we too often see furnaces crack and bricks fly and break with the first impressions of a powerful heat. This defect most frequently proceeds from the nature of the argils; but sometimes also it arises from bubbles of air, which have been inclosed in the substance of the sides, and which, being dilated by heat, can find no other means of escaping than by bursting the matter in which they are enveloped.

To prepare potter's ware for receiving, without danger, the heat necessary for baking, it is exposed for some time to the air: the water with which it is impregnated gradually escapes; the contraction takes place insensibly and without danger; and when all the water that can be evaporated by the natural heat of the atmosphere is dissipated, and the articles have acquired the same degree of dryness through the whole substance of their sides, they may then be baked without fear. Many precautions are necessary, however, to arrive at that result.

The statuary makes his figures hollow, lest their substance should be too thick, and very difficult to be dried.

The potter first exposes his vessels in the shade; and gradually submits them to a warmer temperature, before he commits them to the oven. All graduate the fire in baking, in such a manner as to arrive but slowly and by very regular degrees at the heat which is necessary.

Means have been found to correct, in part, these two defects of argils, that of flying, and that of contracting, by paying particular attention to their preparation, and by mixing them with other bodies.

Before the clay is used, it is wetted with water, and left in holes or troughs to impregnate itself with that liquid, till it is thoroughly penetrated with it. This preparatory operation divides the clay to such a degree, that it at length forms a liquid paste without lumps; it separates from it some foreign bodies which are precipitated, and decomposes the remains of the metallic sulphurets, which are more or less abundant in argils. The longer clay is thus left to steep the better it is.

The clay is next taken and formed into cakes; these are dried in the air, to give them the consistency requisite for being wrought either by the wheel or in moulds.

Before the clay is used, it is kneaded with the hand, so as to render the mixture equal throughout, and to extract from it the foreign bodies that may happen to be in it; in a word, to dispose it to take, under the hand, any form that is intended to be given to it.

Independently of this preparation, which alone is sufficient in many operations, it is usual, especially if it is designed to give a high finish to a work, with respect to figure and the polish of the surface, to mix with the clay refractory bodies, not liable to contraction, and capable of a perfect combination with it. These are always chosen from among the quartzose sands, white quartz, or highly calcined argils.

These bodies, kneaded and thoroughly mixed with argil, form a very porous kind of dough, all the parts of which are combined by the argilaceous cement. They have the advantage of diminishing the contraction by the influence of their whole mass, since they themselves are

not liable to it; and, in the second place, of more readily affording a passage to the humidity which evaporates, because they give to the substance a greater porosity than argil alone possesses.

When you have not at hand a quartzose sand of sufficient fineness and quality, you may employ the stones of white quartz, which are very commonly found in the beds of rivers that descend from primitive mountains.

To render them fit for use, nothing more is necessary than to pulverize them. For this purpose they are made red-hot, and thrown into cold water; which renders them fit to be conveniently broken to pieces by the hammer, the pestle, or the mill. When you perceive among these pebbles any that have green or yellow veins, throw away the coloured pieces as most fusible, and keep only what is white.

The fragments of an oven, pieces of brick, broken crucibles, or stone retorts, may be used instead of quartz, in the construction of furnaces.

The artist has it not in his power to vary at pleasure the proportions of argil and sand; they are determined by the very nature of the

clay. That which is fat and binding will take a much greater quantity than such as is poor or short. If there is too much clay, the composition flies and cracks; if the quartz is too abundant, the mixture has not sufficient consistency, and the composition will neither bear shaking nor carriage. Experience alone is capable of teaching what proportions are most advantageous to be employed.

Argil frequently contains some portions of limestone, which pass over to the state of lime by calcination, and afterwards effloresceing by the contact of the air, remove in scales the portion of wall which covered them, and expose to view white spots which fall into dust.

In order that a furnace should produce all the effect that can be desired, the materials which compose it must be bad conductors of heat: for this reason metal furnaces are the worst of all.

It has been proposed to mix charcoal with the composition itself; but, in this case, it ought not to be employed in too large a proportion. It is likewise usual to cover with cloth furnaces which receive but a slight degree of fire, to prevent the loss of heat; and a

covering may be formed of charcoal, straw, and clay, to concentrate heat in all cases in which it is raised to a high degree in the furnace.

SECTION II.

General Principles relative to the Choice and Employment of Combustibles.

It is not sufficient to procure good materials for the construction of furnaces, it is likewise necessary to make choice of a combustible suited and adapted to the operation.

Not only do the various kinds of combustibles, employed in manufactures, produce heat of different degrees of intensity, but the diversity of their nature requires that furnaces be constructed in a particular way, and used in a totally different manner.

The combustibles employed to produce heat may be confined to two classes, *coals* and *wood*.

The coals are subdivided into *pit-coal* and *charcoal*. *Turf*, which is used in some countries, naturally belongs to this class.

Of pit-coal there are very great varieties. Some kinds contain nothing but a greasy bitumen, burning with facility, increasing in bulk with heat, caking into a mass in the fire-place, leaving little residue, and not exhaling any sulphureous smell. These may be kept without alteration or efflorescence, and form a combustible of excellent quality.

There is another kind of coal, easily broken, ponderous, black, exhibiting, when broken, yellow spots, or veins of the same colour, burning with great facility, yielding even a brisk flame, but not affording a combustion of any duration. This kind becomes heated, and frequently takes fire in the warehouses, but oftener still in the open air: it is then completely decomposed, leaving a residue of a reddish yellow, which may be used for the same purposes as puzzolana. This coal is attended with the disadvantage of exhaling a great quantity of sulphur, and of decaying vessels of copper or iron, by causing those metals to pass into the state of sulphurets.

Nature presents to us other kinds of coal, black, hard, and compact, which might be taken, at first sight, for schists; they appear, in fact, to be nothing but veins of that stone impregnated with bitumen. In general, these kinds of coal are sulphureous; and they are wrought for the purpose of making alum and copperas. They yield but little flame, and leave a very considerable residue, which retains the form, and nearly the bulk of the coal employed.

We likewise meet with a coal that is friable, often humid, and crumbles into dust by long contact with the air and water. Properly speaking it is but a bituminous pyrite, which cannot be employed for any other purpose than the calcination of limestone.

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ferred to pit-coal: but the sulphur which it contains in greater or less quantity destroys the furnaces, corrodes the boilers, and renders all metals wrought by the forge short and brittle. Compared with charcoal it has the further disadvantage of producing smell and smoke, of not burning well except in a large mass, and of being incapable of graduation in its action with the same facility.

When the only object in view is to obtain heat from coal, it is prepared by a carbonisation nearly similar to that which charcoal undergoes.

This carbonisation is effected in the following manner: Raise a heap of coal into the form of a pyramid; make a chimney in the middle, and galleries below, to produce a current of air. Throw lighted coal into this chimney; the fire extends by degrees to the whole mass. When the flame begins to escape at the sides, cover them with damp earth to stifle the combustion. Close, at the same time, all the lateral apertures, and the chimney which had served for air. When the mass is cold a light spongy matter, which is called

tion to strip the wood of its bark previous to carbonisation.

Charcoal made from leaves and shoots of a year's growth is light, without consistence, and soon consumes.

The charcoal from trunks and old branches is porous and foliated; it crackles in the fire, and wastes itself in sparks, if the fire be stirred ever so little.

Stems of three or four years, stripped of their bark, furnish the best charcoal.

The manner of charring wood has also a very powerful influence on the quality of the charcoal.

Wood may be inclosed in iron tubes, to which a sufficient degree of heat is applied to convert it into charcoal. This method is preferable to every other for obtaining good charcoal; but it is expensive, and can only be practised for delicate operations. It is employed in some countries in order to produce an excellent charcoal, with which gunpowder of a very good quality may be made.

Charcoal may likewise be made by burning wood in holes till the space is filled with charcoal: it is then covered with some wet substance,

on which is quickly thrown a deep layer of earth to retard the combustion. In a few days the covering is removed with care, and the charcoal taken out of the hole. This process is generally employed to prepare the charcoal which is intended for making gunpowder.

The third method of charring wood is that which is universally practised in the forests. It consists in piling together a heap of wood, more or less considerable, and contriving currents which run from the circumference to the centre, and unite in one common chimney. This pile of wood is lighted in the middle, and when the flame begins to escape on the outside, the whole surface is covered with earth; the air-holes are stopped; the combustion is thus extinguished, and the operation continued by means of the heat, till the whole is converted into charcoal.

It has been observed, and when I was at the head of the administration of salt-petre and gunpowder works, I had occasion to verify the observation, that charcoal produced from the same wood, but made in a hole, is invariably lighter, and less hard than when made in the open air.

Besides the difference of quality arising from the method employed in the carbonisation, charcoal likewise varies from having been more or less recently made. Fresh made charcoal possesses properties which it loses by age: it not only effloresces, in time, but also imbibes water in the proportion of twenty and twenty-five per cent. of its weight. It has accordingly been observed for some years past, that to make good gunpowder, it is of much less importance to pay attention to the qualities of the saltpetre and sulphur, than to employ fresh charcoal which has undergone none of the alterations that result from long exposure to the air.

Charcoals, in general, give little flame and produce a great heat, so that they are preferable to wood in all the operations of fusion, in which it is necessary to apply to a body a strong and long-continued heat.

Some woods are likewise preferable to others for producing flame and heat: hard woods give more heat than flame, and consume slowly; white woods are soon spent, but they give a good heat and a clear flame; resinous woods

burn well, and give much flame, but they emit a very troublesome smoke.

In all the establishments in which a bright, strong, clear flame is required, as in glass-houses and porcelain manufactories, they take the precaution to cut the wood longitudinally, to divide it into very thin pieces, and to dry it with care. By these means it not only burns with facility, and produces a great heat, but it does not introduce into the interior of the furnaces those currents of aqueous vapors, which, besides the natural effect of retarding the baking, cause the vessels exposed to their action to break.

It seems scarcely necessary to observe, that the climate, the exposure and the nature of the soil, modify the quality of wood in a very remarkable manner. It is generally known that wood exposed to the south burns better than other wood of the same kind which has a northern exposure. The same difference is observable between that which grows in a dry soil, and that which is reared in fat and moist lands.

The periods of the year in which wood is cut are likewise productive of differences. Wood

felled in spring or summer is of bad quality, and burns ill; and none but winter-felled wood is capable of producing, in combustion, all the heat that can be expected from it, as at that season the sap of the vegetable has become solid.

The comparative effect of coke, coal, charcoal, and oak, employed to evaporate any given quantity of water, presents the following proportions:

Coke -	403
Coal -	600
Oak Charcoal	600
Oak -	1029

SECTION III.

Principles relative to the Action of Air in Furnaces.

[illegible] combustible is employed, its ac- be assisted by means of air; and the [illegible]lying this fluid to combustion in [illegible]serves so much the more attention

from us, as it is the most difficult, as well as the most essential part in the operations performed with fire.

Furnaces are fed either by currents of air, which rush from the atmosphere into their fire-places, or by means of bellows or trunks, which drive currents of air upon the combustible.

In the first case, the draught must be determined by chimneys; and to conceive the effect of these tunnels, the base of which rests on the fire-place, it is sufficient to consider that the column of air which fills the chimney being once dilated by the heat, is less dense than the columns of ambient air, so that it must be continually expelled by the external air, which rushes for that purpose to the fire-place.

The air of a chimney dilated by heat may be considered as a lighter fluid than atmospheric air, and which must necessarily rise with a rapidity proportionate to the difference of gravity, so that a rapid and incessant current of external air through the fire-place must be established, in order to expel and occupy the place of that which rises.

Hence it follows: 1. That the higher the chimney of a furnace is, so much the stronger will be the draught, provided the column of air can be heated and rarefied throughout almost the whole length; for otherwise the circulation will only be impeded. 2. That the draught will be more rapid, the thicker are the sides of the chimney, or the worse conductors of heat are the materials of which it is constructed; because the heat being then retained within the chimney, the columns of external air are less dilated by it, and consequently more dense, and better adapted by their excess of weight to expel the rarefied column in the chimney. 3. That the size of the chimney has no kind of influence over the draught, and that, in this respect, the dimensions should be determined by the volume of the column of air transmitted by the fire-place. 4. That the draught of a chimney may be ascertained by introducing an inflamed body into the interior of it.

In furnaces, in which the combustion is produced by a free current of air, it is necessary, that besides a chimney there should be a fire-place and an ash-pit. In those, on the con-

trary, in which the current of air is owing to the effort of bellows, the chimney and the ash-pit become useless, and the fire-place alone is sufficient.

Another difference of construction between furnaces with a free current and those with a forced current, is, that the combustible should lie upon a grate in the former, that the air may circulate through the mass, and inflame it by the rapidity of its passage; whereas, in furnaces with bellows it is sufficient to place the combustible before the tube of the bellows.

From these observations it is evident, that furnaces with bellows can be fed only with coal, while the others are capable of consuming every kind of combustible.

ARTICLE II.

Application of Heat by the Burning-glass and Blowpipe.

The chemist possesses other means besides furnaces to apply heat to the bodies on which

he operates: and he employs with advantage the focus of the burning-glass and the blow-pipe.

At the beginning of the last century, in 1702, Homberg communicated to the Academy of Sciences a great number of facts relative to the action exercised on bodies by the focus of Tschirnhausen's burning-glass. Geoffroy directed his attention to the same subject, and published the results of his experiments in the Memoirs of the Academy of Sciences for the year 1709. These ingenious experiments were resumed in 1772 by Messrs. Cadet, Brisson, Macquer, and Lavoisier, and successively executed with three different burning-glasses.

The first, known by the name of its inventor, Tschirnhausen, was that used by Homberg; it was convex on both sides; the diameter was thirty-three inches, and it weighed one hundred and sixty pounds.

The second, which belonged to the Count de la Tour d'Auvergne, was of the same diameter.

The third is the celebrated lens executed by the direction of M. de Trudaine, the effect of which surpassed every thing of the kind that

was ever known. It was composed of two large glasses curved into a portion of a sphere, and joined at the edges so as to contain alcohol. These glasses were without flaw. They were eight lines thick, and formed two portions of a sphere of eight feet radius, leaving between them a lenticular vacuum four feet in diameter, and containing one hundred and forty quarts of liquid. It was executed by Bernières, and placed in the garden of the Infanta in 1774.

The focus of this lens was at the distance of ten feet ten inches, and one line from the centre of the lens; it formed a circle fifteen inches in diameter. The French academicians increased the power of this focus, by concentrating the rays into a still smaller compass, by means of a second lens of a shorter focus, placed in the cone of the rays refracted by the large glass. We shall state the result of the experiments, made with this lens, when we give an account of the action of different degrees of heat on certain bodies.

Mineralogists have taught us to produce a prompt and intense heat by means of the blow-pipe. It appears that this instrument was first

applied to the examination of minerals by the celebrated Andrew de Swab. After whom Cronstedt, Rinmann, Engestroem, Quist, Gahn, and Scheele, derived the greatest advantage from it in the analysis of earths and metals.

In 1780, the celebrated Bergmann published a series of experiments, comprehending the essay of almost all known minerals by the blow-pipe. To support the matters which he subjected to this essay, he employed charcoal of birch-wood, or that of pine-wood, well burned, cut into parallelopipedons, and a small gold spoon. He made use of one or the other, according to the nature of the substance which he was desirous of trying.

Since that able chemist, Mongez junior has added considerably to the number of experiments, and given some of the results in the notes with which he has enriched his translation of Bergmann's Sciagraphy.

M. de Saussure has likewise improved this department of chemistry. In 1775, he began by substituting, instead of the support before employed, and which had been found to exercise an action on the matters subjected to experiment, a glass tube, at the end of which he

stuck the fragment of the fossil he wanted to melt; but this tube being attended with several inconveniences, such as breaking by the action of the heat, or becoming soft, and enveloping the fragment under experiment, so as to skreen it from the action of the flame, that celebrated naturalist employed in its stead a needle or fibre of cyanite. This stone is infusible with the blowpipe; it may be divided into very small filaments, and it is sufficient to wet the tip of the cyanite with weak gum-water, to agglutinate it to the fragment under essay, which is then exposed to the point of the flame. To manage the cyanite more conveniently, it must be fastened to the extremity of a glass tube, so as to reach beyond the tube. With these precautions he succeeded in melting very fine lamina of crystal.

M. de Saussure did not stop at improving the art of operating with the blowpipe. He likewise described with the most scrupulous attention all the phenomena exhibited by bodies in their fusion, and he was enabled to reduce to six the different kinds of fusion obtained with the blowpipe.

1. Most frequently the melted matter col-

lects into a button larger than the unfused part of the fragment on which it rests. This is the case with feld-spar, talc, and mica.

2. Sometimes the melted matter instead of remaining together on the top of the pyramid, runs down its side; and the point of the pyramid, instead of becoming flatter, grows sharper.

3. M. de Saussure observed, that, in various cases, the bottom which rests on the cyanite melts first. Here the cyanite and the fragment under essay act upon each other; and it is then necessary to fix the body under experiment on the point of a piece of the same substance.

4. A fourth mode of fusion is that of the minerals which begin to swell on the first impulse of the fire, and afterwards become extremely refractory. Such are the green schorls of Dauphiné, the deodatite, &c.

5. A fifth method in which the flame of the blowpipe acts, consists in producing an almost imperceptible swelling, by developing small bubbles in the interior of the body, though the latter does not run or assume the form of globules, and though the figure and proportions of its dimensions do not appear to be sensibly al-

tered. It is in this manner that the flame acts on the red cornelian.

6. Lastly, there are fossils which, being refractory, and composed of grains that adhere to each other only by a small number of points, do not unite by fusion, but form small, detached, melted grains. The emerald is particularly distinguished among this class.

After discriminating the different kinds of fusion obtained by means of the blowpipe, M. de Saussure endeavoured to determine the different degrees of the fusibility of bodies, by the diameter of the glass globules. Having ascertained by Wedgwood's pyrometer the degrees of heat necessary for melting a cube of window-glass and a cube of feld-spar, and comparing the diameters of the globules of glass and feld-spar formed by the blowpipe, you find with how many degrees of Wedgwood the mutual relation of these diameters corresponds.

From the methods of measuring heat we shall perceive that, in Wedgwood's pyrometer, the action of the fire increases, beyond certain limits, with a rapidity of which our senses are not capable of judging. The degree at which

copper melts is twenty-seven; and that required to melt cast iron is one hundred and thirty—a difference too extraordinary for any one to have imagined.

In order to make comparative experiments it is therefore necessary to employ the flame of a steady candle, an air almost always the same, a continual, rapid, and voluminous current.

All these conditions render experiments a delicate task, and have this effect, that the results are not always fit subjects of comparison.

No sooner was oxygen gas discovered than chemists conceived it possible to avail themselves of its aid, in order to produce a degree of heat superior to any that had been previously obtained.

M. Achard, of Berlin, seems to have been the first who employed this gas for fusion. He made use of bladders fastened together, and communicating by glass tubes; and conveyed the current of oxygen gas over the flame of a lamp. By this method he melted platina and iron.

In 1782, Lavoisier published a circumstantial description of an apparatus adapted to the convenient reception and supply of gas, in order to propel it against the ignited combustible.

By a considerable series of experiments, detailed in three memoirs which appeared at different times in 1782 and 1783, he demonstrated the possibility of obtaining, by this method, a degree of heat superior to that which the best burning-glasses were capable of producing.

This kind of hydrostatic bellows has since been improved by Meunier, who had two of them constructed, a description and engraving of which may be seen in Lavoisier's *Elements of Chemistry*, and in a memoir which Meunier himself published on the subject.

Lavoisier's experiments were made with oxygen gas, extracted from red oxyd of mercury. That which is procured from nitrate of potash appeared less active.

Gullisch, Gutling, Furstenberger, Geyer, Ingenhousz, Ehrmann, and others, have successively melted with this gas, and varied the apparatus employed to collect and to blow it.

Ehrmann, in particular, made a series of very numerous experiments on the action of oxygen gas on various bodies; and he published the results of them in 1787, in his *Essay on the Art of Fusion by Means of the Air of Fire, or Vital Air.*

M. Guyton Morveau resumed these experiments in the Polytechnic School, and communicated the results to the public in the journal of that institution. His apparatus consists of a bladder provided with a pipe, with which he propels the oxygen gas over the flame of a candle, and presents a luminous dart to the body on which he is about to operate.

Nothing more is necessary than to blow the current of oxygen gas on the charcoal slightly kindled, in which a small excavation is made to receive the matter under experiment.

SECTION V.

Application of the preceding Principles to Furnaces of Fusión.

Fusion may be defined, the passage of a solid body to a liquid state by the action of caloric.

Furnaces of fusion are generally employed for working metals, stones, or glass.

They are heated with coal or wood, according to the greater or less facility of procuring

one or the other of those combustibles, and according to the substances that are to be heated. For example, refractory ores, such as those of iron, are melted and reduced with charcoal in preference to pit-coal, which renders metals more or less brittle. The furnaces of glass-houses, for making of flint-glass, are heated with dry wood; and if coal be employed, care is taken to preserve the materials from the contact of the fuliginous smoke, by covering the pots.

The air is propelled into the fire-place sometimes by a free current, sometimes by bellows or trunks: to the first class belong the furnaces of glass-houses, reverberatory furnaces, &c. to the second forges, hand-furnaces, &c.

This distinction between *wind-furnaces*, or furnaces *with a forced current*, and furnaces *with a free current of air* is so much the more necessary, as their construction is totally different. We shall proceed to examine them separately.

ARTICLE I.

Wind-Furnaces, or Furnaces with a forced Current.

The most simple wind-furnace of all is the smith's forge. Its construction, equally simple and economical, permits the workman to heat successively every part of a long bar of iron; it enables him with ease to blow the fire, to stir it, to take away, and replace his materials, and to judge every moment of the degree of heat, and the state of the metal.

The forge of a chemical laboratory differs in no respect from that of the smith, except that the combustible is contained in a portion of a cylinder, which is, in general, from ten to twelve inches wide, and six or seven deep. It is usually covered with a dome, in the middle of which is a chimney. This furnace is of great use in our laboratories, not only for melting or calcining any matter, but even for making a fire, in order to perform operations with other apparatus. *See Plate* I. *fig.* 1.

But the forge which is in most common use in our laboratories produces very inferior effects, in comparison of the forge with a triple current of air, which was first constructed in the laboratory of the School of Mines, and which is now set up in many other places. The air, expelled from the bellows by a very wide pipe, passes into a cylindrical reservoir, about nine or ten inches wide, to the lower part of which are adapted three tubes, about an inch in diameter, which convey the air to the forge through three different apertures, very near the bottom, in the middle of the three sides of the forge. The forge is constructed with bricks firmly held together by iron bands which go round the outside; it is from twelve to fifteen inches high, seven or eight wide, but at the height of six inches from the bottom it is made one or two inches wider. *See Plate* I. *figs.* 2 *and* 3.

The vessels made use of to expose mineral substances to the action of fire in forges are called *crucibles*. They have almost invariably the form of a cone with the top cut off. *Plate* I. *fig.* 4.

In large manufactories, such as glass-houses, they employ pots or crucibles capable of con-

taining eight or ten hundred weight of matter, and the form given to them is that of a portion of a cylinder, because it not only best resists the effort of the mass contained in the vessel, but is the most easily constructed.

Crucibles are made of earth, plumbago, or metal. With clay and sand it is possible to make crucibles which shall neither fly nor enter into fusion with the degree of heat that is applied to them; of this kind are the Hessian crucibles. But these vessels are attended with this inconvenience, that they mingle some particles of their principles with the substances which are heated in them, especially if the latter be of the nature of alkalis, acids, or salts. This has obliged the chemist to substitute in their stead crucibles of platina or silver for the last mentioned operations; and to confine the use of the Hessian crucible to operations performed on metals.

The crucibles of plumbago are made with the mineral of that name, and a small quantity of argil, which are kneaded together to give the mixture the requisite consistence; these resist the most violent heat of our furnaces, and are much used for the melting of metals for

coinage. But the nature of their constituent principles, iron, carbon, and argil, limits their utility, and prevents their being employed in the treatment of salts.

The crucibles which combine the greatest number of qualities are those of platina. This metal, infusible at the degree of heat obtained by our furnaces of fusion, is likewise unassailable by pure acids, salts, and alkalis. It therefore possesses all the properties that can be desired for the purposes of our analyses; but it is to be regretted that the scarcity of this metal, and the difficulty of working it, render vessels of platina so extremely dear.

Silver crucibles possess part of the properties of those of platina, inasmuch as they are unassailable either by alkalis or neutral salts; but they cannot endure the same degree of heat, or be substituted for them in all cases.

Iron crucibles resist heat extremely well; but the air, aided by the action of the fire, oxydizes them very speedily; saline matters consume hem; some metals incorporate with them, nay even earths become coloured in them; so that these crucibles cannot be employed for fusion, except in very few cases.

When a crucible is used in the forge, it is placed on a small round earthen stand, as large as the bottom of the crucible, and very refractory. The stand raises the crucible, so that the bottom of it is on a level with the apertures by which the wind of the bellows is discharged. When the substance that is to be melted is put into the crucible, it is covered with a lid made of the same material, to prevent coal from falling into it. When the matter is melted, and you design to run it into ingot or other moulds, you lay hold of it with a pair of crooked tongs, which embrace its whole circumference, and prevent the possibility of any accident. *Plate* I. *fig.* 6.

The crucibles which are employed in glass-houses are composed of raw clay, mixed in due proportions with baked clay, proceeding from broken pieces of old pots. In this instance quartzose sand cannot be employed, because, as alkalis form the base of the composition of glass, they would dissolve the quartzose portion of the crucibles, and accelerate their destruction. On the composition of these crucibles, in particular, the utmost care should be bestowed; for being incessantly exposed to the

consuming action of a very powerful fire, and to the effort of the enormous mass of matter which they contain, they ought to oppose an equal resistance at every point, so as not to suffer the fire or the matter in fusion to make more impression on one than on another. The reader will be much more sensible of the importance of bestowing particular care on the selection of materials, and on the fabrication of pots for glass-houses, when he considers, that the necessity of replacing these crucibles, which are very expensive, is attended with a suspension of business, or, at least, occasions considerable derangement.

In the operations performed on ores for the purpose of extracting the metal by fusion, they generally employ large bellows made of wood, and with a single bottom, so that, to obtain a constant current of air, it is necessary to place two of these instruments beside each other, and to make them act alternately. They are almost always worked by means of the axle of a wheel moved by water.

The use of trunks has been introduced for a variety of purposes, and the effect which I have seen them produce has convinced me that not

only the air they discharge raises a greater heat, but that their action is infinitely superior to that of the strongest bellows. I shall here give the figure and dimensions of the trunk which produces the best effect of any I have yet seen. *Plate* II. *figs.* 1 *and* 2.

Take a cask, *dddd*, four feet six inches wide, four feet eight inches high, with the bottom knocked out, and plunge the lower part into water to the height of seven inches and a half. In the middle of this cask is placed a stone, *e*, rounded off at the top, standing in the water, and rising about eleven inches above the surface of the liquid. In the upper end of the cask is made a hole, to which is adapted a leathern pipe, intended to convey the air to the fire-place, which is to be supplied with it. From the top of the cask rises a hollow cylinder, eighteen feet in height, and eighteen inches wide within.

This cylinder grows narrower towards the top, and opens externally by four apertures about five inches wide, situated on the four sides of the cylinder *cc*.

On the top of this cylinder is a hollow cone, the base of which forms one of the sides of the

apertures. This cone is six feet in height, the opening at the upper end is eighteen inches wide, and that at the lower end five inches.

This brief description will suffice to give an idea of the action of the trunk. A current of water is brought from above the funnel which crowns the trunk; the current rushes into the tree of the trunk, and is broken by the stone placed in the middle of the cask; the air which is disengaged from it being unable to ascend again, on account of the continual fall of the water, is obliged to escape by the lateral opening, g, which conveys it to the fire-place.

In some of these machines the trunk is made without holes, so as to form merely a hollow cylinder, surmounted by an inverted funnel, and supported by the cask; but I am far from considering these apertures as useless. I have constantly observed, that when the water precipitates itself into the tree, a rapid current of air rushes through them with such impetuosity, that a handkerchief held near them is forcibly carried into the inside.

Thus the air of trunks proceeds not only from that which is in the water, but likewise from the current formed by the apertures.

I made an experiment, which demonstrates, that the most quiet water contains a very considerable quantity of air, which may be disengaged by the mere shaking or the fall of that liquid. For this purpose, it is sufficient to place a metal tube at the bottom of a tub full of water, and to pour it into a cask placed under the tube, and disposed as in the ordinary trunks. By this method a prodigious quantity of air is disengaged; but what is truly surprising, is, that if the water be repeatedly put back into the tub, and poured off again in the same manner, it still continues to furnish a very considerable quantity of air.

In large establishments, where they have occasion to melt considerable quantities of matter at once, furnaces are constructed with bricks, or at least their interior is lined with them. These bricks should be perfectly refractory; and on this subject we could only repeat what we have already said concerning furnaces and crucibles, were we to enter into any details on the care which it is necessary to bestow on the selection of the materials employed in their composition.

The form of wind-furnaces of fusion varies

according to the nature of the mineral that is wrought in them. It would lead us into a discussion much too prolix were we to attempt a description of them all. We shall therefore content ourselves with giving, in this place, the figure of that which is most generally employed in the smelting of iron ore. *Plate* II. *figs.* 3 *and* 4.

In all furnaces the mineral is thrown upon the fuel, which forms a thick mass, so that in passing through it becomes heated, is reduced, and in a state of fusion before it reaches the basin, where it receives the most violent blast, and where the matter is refined by heat and rest.

ARTICLE II.

Furnace with a free Current of Air.

The heat of a furnace is the stronger the more rapid is the draught; and this essentially depends on the proportions that are given to the different parts composing the furnace.

In all furnaces with a free current of air, a careful distinction must be made between the ash-pit, the fire-place, and the chimney. In most there is a fourth part, called the *floor*, or the *laboratory*. This, in all of them, is a space between the fire-place and the chimney, where the metal intended to be melted is put.

The floor is subdivided into two parts, which the French distinguish by the appellations of *autel*, or the altar, and *creuset*, the crucible. The first is next to the fire-place; there the metal to be melted is deposited. The second is the opposite part, next to the base of the chimney, and receives the metal as it runs off.

The ash-pit should be wide, deep, and protected from too rapid currents of external air. It is separated from the fire-place by a grate which supports the fuel, the bars of which should be at such a distance that the coal cannot fall through, but nevertheless not so close as to interrupt the passage of the air. To judge of the draught of the furnace, and to prevent the grate from being choked, you may place a basin full of water on the bottom of the ash-pit; the vivid light of the grate reflected in it shews, every moment, what points are choked,

on which you restore the draught by removing with an iron poker the matters which obstructed it, and by raking out the scoria.

We shall content ourselves with giving, in this place, a representation of three furnaces of fusion with a free current, which produce the most powerful effect, and which are most commonly employed in operations.

The first (*Plate* III. *fig.* 1.) is the melting furnace of our laboratories, improved by Lavoisier; it stands on a trevet, and draws in the air with its whole bottom, which is open. It is used with the greatest success for melting in crucibles. It is reduced in the engraving to one-twelfth of its actual dimensions.

The second (*Plate* III. *fig.* 2.) is a furnace, very commonly employed for melting metals in the laboratories of mints.

In these two furnaces no distinction is made between the fire-place and laboratory; the crucible is set in the fire-place, and covered with coal.

But we have already observed that there are furnaces, in which the floor or laboratory is situated between the fire-place and the chimney. In these the flame, which rises from the

fire-place, strikes against the arch over the floor, and is thrown back with violence on the spot where the matter to be melted is put. This has occasioned these furnaces to be called *reverberatory furnaces*. They are used for smelting metals. (*See Plate* III. *fig.* 3.) They are likewise employed for calcining or oxydizing metallic substances, and often for extracting the most fusible metals, as lead, from their ores. In this latter case it is necessary to mix wood-charcoal with the ore, as well to reduce the metal, as to prevent its ulterior oxydation.

The slightest inspection of the structure of the two first mentioned furnaces with a free current will satisfy the spectator that wood cannot be employed in them for fuel; but the case is different with respect to the third. In this the effect is produced at a certain distance from the fire-place; it is entirely owing to the flame; and under this circumstance dry wood is productive of the best effects.

When the furnace is heated with coal, it is sometimes thrown in through a perpendicular aperture made in the arch which covers the fire-place. It is more frequently introduced by lateral apertures, that are nearly level with

the grate, and these apertures are filled up with coal, so that nothing more is necessary than to push it into the fire-place whenever occasion requires.

The only modification that is made in the reverberatory furnace, when it is heated with wood, is to lower the grate; because the flame, which is stronger, would then pass over the floor, and be partly lost in the chimney.

SECTION VI.

Application of the preceding Principles to Furnaces of Evaporation.

Evaporation signifies the conversion of a liquid into vapours by means of caloric.

The object of this operation is either to separate matters from each other, one of which at least is liquid, and which possess a very different degree of volatility: or to concentrate a solution by the subtraction of a portion of the liquid, in order to obtain separately the substance which is in the liquid.

Evaporation is performed in furnaces, which, from their use, are called *evaporating furnaces.*

The evaporating furnace is generally composed of two distinct parts, the *ash-pit,* and the *fire-place.* They are separated by a grate which supports the fuel; each of these parts has an aperture, one of which affords a passage for the air, and for taking out the ashes, while the other facilitates the use of the fuel. In the furnaces in which wood is used there is no ash-pit; and in this case, the current of air is formed by the door of the fire-place, where care is taken to keep lighted coal or wood, that the fresh air may not rush against the evaporating vessels and moderate the heat.

The simplest of all evaporating furnaces is that of our laboratories; it is shaped like a portion of a cylinder open above; at the top three or four holes are made in the wall to afford a passage to the current of air, which, after animating the combustible, must escape from the furnace. *Plate* IV. *fig.* 1.

A great variety may be observed in the evaporating furnaces that are in use. The form of the vessels employed for evaporation, and

the nature of the substance evaporated, must necessarily occasion many modifications in their construction; we shall confine ourselves to a description of the principal ones.

The boilers, or pans, used in manufactories, may be considered as the most common evaporating vessels. They are employed to concentrate and thicken liquids, or to separate the salts or other substances which may be contained in them. The form usually given them is an oblong square, but sometimes it is circular.

Before the construction of furnaces received the improvements that have been of late years made on them, boilers were merely fixed on four walls, in such a manner that the fire-place occupied the whole length and breadth, except about three or four inches on each side, where the boiler rested upon the walls. A door made in the middle of one of the walls facilitated the use of the fuel, and afforded a passage for the air; the chimney was constructed at the opposite side.

From the idea we have given of the bad construction of our ancient furnaces, it is obvious that the current of air established between the boiler and the bottom of the fire-

place carried away the heat, and threw almost all of it into the chimney; so that it required a great length of time, and a prodigious quantity of fuel to produce an evaporation.

The progress of science, and the necessity of saving both time and fuel, could not fail to introduce changes in the construction of the furnaces, of which we are about to treat.

The construction of a furnace cannot be pronounced good, unless the heat be equally applied to every point of the surface of the evaporating vessel, and unless all the heat produced by the combustion be advantageously employed.

It may therefore be asserted, that there exist imperfections:

1. Whenever only one of the surfaces receives heat, because the general mass of the liquid is heated only in proportion to the transmission of the heat by that part of the furnace, and of the liquid which immediately receives it: so that the operation is prolonged.

2. Whenever the chimney is seen to smoke; for this smoke, composed entirely of combustible bodies carried away by the current of air,

announces that they have escaped the combustion.

3. Whenever a strong impression of heat is felt in the current of air which passes away through the chimney.

By making some changes in each of the parts belonging to an evaporating furnace, it has been at length brought very near to perfection.

When coal is employed, and an ash-pit is consequently necessary, care is taken to make it deep, both to prevent the small lighted coals which fall, and the heat of the grate from warming the contiguous air, and to protect it from the currents of external air, which incessantly varying in force and direction, render the combustion unequal.

The fire-place and the chimney require particular attention. The grate should occupy two-thirds of the length, and one-third of the breadth of an oblong boiler; it ought to be placed about three inches below the stone on which the door rests, so that there may be a slope in the thickness of the wall against which the grate is supported. The grate should be formed of iron bars laid without fastening, on

stands of the same metal, placed across, and about an inch distant from each other. Iron bars, which are fixed or fastened, are liable to twist and warp from the change of dimensions which they undergo in passing successively from cold to heat, and from heat to cold. The boiler should be placed ten or fifteen inches above the grate; the nature of the fuel principally regulates the height, according as it gives more or less flame, or burns with greater or less activity.

The heat arising from a fire-place exercises its *maximum* of action at a height which it is necessary to ascertain, but which varies from the causes we have just mentioned. In general the combustible which yields much flame requires a greater height; that which burns with violence, and leaves but little residue, requires a less height. Between these two extremes a suitable elevation ought always to be taken.

When a round boiler is to be placed on a furnace, it is necessary to make certain modifications in the construction of the latter, especially as far as regards the position of the grate. In almost all manufactories the boiler is placed in such a manner that the centre of its bottom

corresponds with the centre of the grate. This disposition would be better if the heat of the fire-place rose perpendicularly to strike against the boiler; but the current of air which carries away the flame in its passage to the chimney, gives it an oblique direction; so that the current of heat strikes only that part of the boiler which is nearest to the chimney. To obviate this inconvenience, it is sufficient to place the grate more forward, so that the end next to the chimney may correspond with the middle of the boiler, and that the door of the fire-place may be perpendicular with the front, as is represented in *plate* V. *fig.* 1. In this position, the flame which rises from the fire-place rushes with violence against the whole surface of the bottom of the boiler before it is lost in the chimney.

But it is principally in the direction of flues that the most advantageous alterations have recently been made. Instead of being raised perpendicularly from the fire-place, they are made to turn round the side of the boilers before they come to the perpendicular chimney, which immediately communicates with the air: so that the portion of the heat which escapes from the fire-place is applied to the lateral sur-

faces of the boilers on which it exerts its influence.

At the further end of the fire-place, opposite the door, are sometimes made two apertures, which form the commencement of spiral flues, and which unite, over the door of the fire-place, in a single flue, by which the current of air, which has served to animate the fire, escapes into the atmosphere. (*See plate* V. *fig.* 2.) In this case the perpendicular chimney is over the door of the fire-place.

In general, however, the current issues from the fire-place only by an aperture. The spiral flue then terminates in the perpendicular chimney, on the side opposite to the fire-place and ash-pit. *See plate* V. *fig.* 3.

When the boilers are very large, and it is difficult to heat their base without employing a prodigious quantity of fuel, other spiral flues are made to open into those which run all round. *See plate* V. *fig.* 4.

This last construction possesses the advantage of supporting the boilers, and preventing them from protruding, an inconvenience to which boilers of lead and copper are particularly

liable, and which occasion their speedy destruction.

The walls which separate the winding flues of the chimney below the boiler should not be more than a brick in thickness.

At the moment of setting the boiler, the upper surface of these partitions should be covered with a coat of luting, made of horse-dung and argil kneaded together, that the boiler may touch at every point, and that the flame, or current of air, which issues from the fire-place, may be obliged to pass through the whole extent of the chimney.

The furnace of which we are now speaking is attended with very great advantage when wood is used for fuel, because the flame which it produces penetrates the sinuosities of the chimney throughout almost their whole extent, and because the heat is applied to all the surfaces of the boiler.

Notwithstanding the advantages of the spiral chimney in furnaces, there are cases in which it would be dangerous to employ it. In soap-boiling, for instance, the soap would not only be burned by heating the sides of the boiler in their whole height, but it would produce a

swelling of the liquid, which it would be extremely difficult to correct. Accordingly, only the bottom of the boilers used by soap-makers are constructed of copper, the rest being composed of freestone firmly joined together.

Another difference exhibited by boilers intended for soap, is, that the grate, instead of being in front, near the door of the fire-place, is situated at the back part of the bottom of the boiler; so that the flame of the combustible proceeds directly toward the door of the fire-place to gain the chimney by passing underneath the boiler; which is clearly a contrary direction to that which it follows in other furnaces (*See Plate* VI. *fig.* 1.). This curious form of construction has been adopted, because it has been observed, that, by this method, the action of the heat is more equally distributed than in the other furnaces.

We now come to treat of evaporating vessels, which, as we have observed, are the vessels that contain the liquids to be evaporated.

Evaporating vessels are of metal, glass, porcelain, or stone ware. They are denominated *boilers, pans,* and *capsules,* according to their dimensions

A boiler is solidly fixed in a furnace; it is of a square, round, or oblong form; of copper, iron, tin, or lead, according to the nature of the substances for which it is intended. Those of copper are employed in dyeing, and generally in all operations performed on vegetables, for the purpose of extracting certain principles. Those of iron are used in manufactories in which the saline principle is extracted, or in which dissolutions of neutral salts are concentrated. Those of lead, less assailable than the latter by saline dissolutions, are used in alum, copperas, oil of vitriol works, &c. I know of but one purpose to which tin boilers are applied, namely, in dyeing, to dilute the *composition*, or the mordant of scarlet, because that acid liquor attacks the other metals more or less, and the colour is tarnished and injured by them.

The form of boilers has always appeared to me to be an object of little importance, if the furnaces were but well constructed. It is, nevertheless, true, that those of a circular form are more easily heated than the others, and that they are less liable to injury. I should therefore prefer them for the purposes of eva-

poration only; but when it is necessary to work by dipping into the boiler, the manipulations are rendered more easy by the square form: consequently the nature of the operations must decide with respect to the form to be adopted.

The flat bottom of round boilers has always appeared to me to be attended with inconveniencies. 1. It is difficult to empty the bottom of a boiler which has this form; 2. The impurities which often sully the contents, and are deposited over a large surface, remain exposed to the tumultuous action of the liquid; 3. The liquid bears every where with its whole weight on the bottom already weakened by the heat.

By making the bottom of boilers to project inwards, so as to present a concave surface externally, all these defects may be corrected, and other advantages procured. 1. The fire is applied in a more equal manner to every point, from this circumstance alone, that the greatest heat rises in the middle. 2. This internally convex form opposes more resistance to the efforts of the liquid and the action of the heat. 3. The deposits formed in the bath are thrown to the sides of the boiler which rest on the brick-work, where the fire is less active, and conse-

quently where there is less danger of their forming a crust, and interposing between the liquid and the metal, which very often occasions the melting of the boiler. *See Plate* VI. *fig.* 2.

It has long been a subject of dispute what proportions are the most advantageous to be given to a boiler. From the experiments with which we are acquainted, we may now deduce the following consequences: the quantity of fuel necessary for evaporation augments only the volume of the liquid in the same proportion, so that there is an advantage in employing large boilers: but more time is required to bring the latter to ebullition; and as time is an element of calculation in the interest of the manufacturer, it depends on himself to determine the dimensions of his boilers.

Count Rumford kept boiling, at different times, for an hour, four hundred and forty and two hundred and eighty pounds of water. In the first instance eighteen pounds of water were kept boiling by one pound of fuel, and in the second only twelve pounds.

It may be adapted as a principle, according to Count Rumford, that the saving of fuel is

greater in proportion to the length of time necessary for producing ebullition.

The *pans* employed in the shops of the confectioner and apothecary to concentrate juices, to make decoctions, &c. are small, portable boilers, which are placed on the fire-place of a furnace, or merely on a trevet, under which wood is burned. They are of copper or of silver. The latter should be employed in all cases for the concentration of juices or salts intended for medicinal purposes; because copper is liable to be corroded and dissolved, and that metal would impart very pernicious qualities to medicines. But as, in our domestic economy, we may not have silver pans at our disposal for the preparation of extracts for food, we ought at least to be extremely cautious in the use of copper. It should be rubbed with care to remove the rust or verdigrease which is so easily formed on the sides. In the south of France, where they prepare great quantities of the extract of grapes, called *raisiné*, they correct, in part, the inconvenience of the copper pans in which this preparation is made, by leaving in them, during the whole operation, iron keys, which, when taken out, are red, and in-

crusted with copper. In this instance the iron precipitates the copper as fast as it is dissolved, and takes its place. The motion given to the liquid to forward the evaporation, and the friction exercised with wooden spatulas on the sides of the vase to prevent the substance which is thickening from adhering to them and burning, facilitate the corrosion and the dissolution of the copper.

The *capsules*, or evaporating vessels employed in our laboratories, have, in general, the form of segments of a sphere, and are made of glass, porcelain, or metal.

Glass capsules are in most general use; but those made in glass-houses have various defects: 1. They are almost always of unequal thickness in different points, which, preventing a uniform dilatation by heat, renders them liable to break. 2. They present two or three prominent points in the convex part, which proceed from this circumstance, that the workman, in order to polish the edges, is obliged to lay hold of them on that side; but these points are frequently the occasion of the fracture of the vessels.

The best capsules are such as you may your-

self prepare by cutting a glass receiver into two semicircular vessels.

This process may be performed in different ways: 1. You may tie a piece of packthread round the receiver at the place where you intend to cut it. Fasten the cord with a lute made of argil and horse-dung kneaded together; heat a piece of iron provided with a handle, and apply it red-hot to the part where the separation is to be made, moving it in that direction for the space of three or four inches. The glass cracks with the impression of the heat, and the crack follows the part that is hottest. When the crack begins, pursue it with the iron, bearing upon it, and the receiver separates into two bowls. I would advise the cleaving of it in the direction of the orifice, because each capsule is then provided with a spout or beak very convenient for pouring, decanting, &c.

When the vessel does not split by the heat communicated by the iron, the crack may be produced by the application of a wet body to the hottest part, or by throwing a drop of water upon it.

2. When you wish to form several small cap-

sules from one receiver, apply an iron ring red-hot to the part you intend to cut, and the capsule is instantly separated.

These capsules, which possess great advantages, from being of equal thickness in every point, have sharp edges, which render them dangerous to be handled, and dispose them to crack with great facility. It is therefore advisable to polish the edges, and round them off by an enamelling lamp.

Glass capsules cannot resist the immediate action of fire without incurring almost the certainty of breaking. To prevent this accident, they are covered with a lute of argil and horse-dung kneaded together, and applied with the hand. In this state they may be used for evaporation, and exposed to the action of a strong and sudden heat without breaking, provided, however, the substance they contain be liquid.

Capsules of porcelain, or stone, endure the application of immediate heat without breaking. The first are of very general use, the second of rather less, because they are always more or less porous.

There are cases in which the heat which

produces evaporation acts only on the surface of the liquid. Of this the evaporation operated by the sun affords an example; and in the southern climates this is the only method employed to concentrate the sea water for the purpose of extracting its salt.

In many establishments attempts have been made to communicate heat, by making the current of hot air pass over the surface of the liquid, after it has heated the base and the sides: so that, by this construction, the heat is applied to all the surfaces, and the current carries along with it, into the same chimney, the vapours of evaporation and the volatile residues of the combustion. In this way the evaporation is doubtless more expeditious, but it is to be feared that much impurity from the fireplace may mingle with the liquid; so that this method is adapted only to certain operations. It might be employed, for instance, to concentrate the leys of ashes for the purpose of obtaining their salts; and instead of using a boiler, it would be extremely economical to evaporate in a reverberatory furnace, the floor of which would serve to receive the liquor. The same furnace might, even without the ne-

cessity of removing the substance, convert the salts into potash.

The manner of applying the fire to evaporating vessels varies according to the nature of the vessels, and to that of the matters operated upon.

We are acquainted with three kinds of evaporation: one is executed with the *naked fire*; that is, the evaporating vessel stands immediately upon the fire; the second is performed with the *sand-bath*; that is, the evaporating vessel is separated from the fire by a bed of sand: lastly, a liquid may interpose between the fire and the evaporating vessel, and it is then called evaporation with the *balneum mariæ*.

The first method, or evaporation with the naked fire, should be employed when it is possible to make use of vessels that resist the action of the fire, as those of metal. It is the most expeditious and economical method, because the heat is immediately applied to the evaporating vessel, but it requires great care in the management of the fire, not only to produce no more than the suitable degree of heat, but also to avoid that inequality which causes a variation in the temperature of the bath, and

changes the nature of the product. *See Plate* VI. *fig. 3 and 4.*

When you employ brittle vessels, such as those of glass, you evaporate with the *sand-bath.* To this end the evaporating vessels must be half buried in a dry fine sand, in such a manner that the bottom of the vessel may be separated from the fire-place by a bed of this sand. The heat of the fire is then gradually transmitted by the sand; and the refrigeration afterwards takes place by insensible degrees, so that the evaporating vessel never receives the sudden impression either of cold or heat, and the operation proceeds with method and regularity, even when you neglect to keep up the same degree of heat in the fire-place. *See Plate* VI. *fig.* 5.

When you have a very light liquid to evaporate, you may put the vessel containing it into a denser liquid. The degree of heat capable of determining the ebullition of the latter, will also produce ebullition in the other which receives its heat; and in this case, the evaporation is performed with the *balneum mariæ.* We employ this method whenever we want to separate a light liquid from its solution

or mixture in heavier liquids, and to disengage a very subtle matter from the bodies with which it is in combination. It possesses an advantage over the two others in not communicating the taste of the fire to the substance which is volatilized. From what has just been said, it is obvious that by thickening water by the solution of any salt, and thus rendering it less evaporable, it may be employed as a *balneum mariæ* for the distillation of such liquids as cannot be raised higher than the degree of boiling water. *See Plate* VI. *fig.* 6.

Besides all the causes of the fixity of bodies which we have already assigned, and which, of course, oppose evaporation more or less, there is one that may be regarded as the principal, since it acts every where with a force equal to the weight of a column of mercury of twenty-eight inches; I mean atmospheric air.

When the weight of the atmosphere is diminished, either by the aid of the air-pump, or by ascending to the summits of the highest mountains, we observe several liquid bodies resolve themselves into vapours, and remain in that state. Speculating on this principle, various persons have, at different times, proposed

methods of distilling or evaporating in a vacuum; but apparatus hitherto contrived for that purpose have very imperfectly accomplished the object of their authors.

SECTION VII.

Application of the preceding Principles to Furnaces for Distillation.

The only difference between distillation and evaporation is, that in the former the product which evaporates is collected, while, in the latter, it wastes itself in the air.

Distillation is employed to separate substances that are mixed together. This separation cannot take place, unless one of them is lighter than the other.

In our laboratories distillation is performed with glass vessels called *retorts*; but in the establishments of the arts, copper vessels, called *alembics*, or *stills*, are employed for the purpose.

ARTICLE I.

Distillation with the Retort.

Though the sand-bath furnace is frequently used for distillation with the retort in our laboratories, yet that which is essentially appropriated to this kind of operation is the *reverberatory furnaces.* This furnace is composed of four principal parts; the *ash-pit,* the *fire-place,* the *laboratory,* and the *dome,* or *reverberator.* The laboratory is formed by a portion of a cylinder, which is separated from the fire-place only by two small iron bars, designed to support the retort. The dome covers the laboratory, and has a hole in the middle to afford a passage to the current of air which escapes from the fire-place. The edges of the dome and of the laboratory are sloped in a semicircular direction, to admit the neck of the retort. *See Plate* VII. *fig.* 1.

The retort is the vessel into which the matter subjected to distillation is put. It is usually formed like an egg, terminated by a neck

inclined and open at the extremity. *See Plate* VII. *fig.* 2.

When the distillation is performed on a sand-bath, retorts, with a tubulure at the top, are employed; and by this tubulure the matter to be distilled is introduced without deranging the apparatus. *See Plate* VII. *fig.* 3.

To the neck of the retort is adapted a vessel destined to receive the product of the distillation. This vessel is called a receiver, and it is in general a sphere with two apertures, one large enough to admit the neck of the retort, the other smaller, to give vent to the gases and vapours which cannot be condensed. *See Plate* VII. *fig.* 4.

Between the retort and the receiver is frequently introduced a glass vessel called an *adopter*, which has the double advantage of removing the receiver to a greater distance from the fire, and of itself receiving part of the products. *See Plate* VII. *fig.* 5.

But were we suddenly to expose a glass retort to the action of the fire, and merely to fit the receiver to the retort before we proceeded to distillation, we should run the risk of breaking the retort, and seeing almost all the pro-

ducts of the distillation escape into the air at the junctures of the receiver with the retort. Means have been found to obviate these accidents by covering the retort with a lute which protects it from the sudden and immediate impression of the fire, and by closing with care all the vents of the apparatus.

I use with advantage a mixture of fat earth and horse-dung. Soak clay several hours in water, and when it is thoroughly impregnated with that liquid, knead it with horse-dung into a soft paste, which must be applied and spread with the hand over the whole surface of the retort that is to be exposed to the action of the fire. The horse-dung unites various advantages: it contains a viscous moisture which hardens with heat, and strongly combines every part; when this juice has been altered by fermentation or age, the dung ceases to possess this virtue. The fibres, or straws, which may easily be distinguished in the dung, contribute to unite and bind all the parts of the lute in the closest manner.

Retorts thus luted withstand perfectly well the impression of the fire; and such is the adhesion of the lute to the retort, that even if the

latter should fly during an operation, the distillation suffers no interruption. But the lute must be applied with care, and dry slowly, lest it should crack. This inconvenience, however, is obviated, by spreading a little more lute on the retort, and retouching the first coat before it is perfectly dry.

To prevent the vapours which ascend in distillation from being dispersed in the atmosphere, the junctures of the neck of the receiver with that of the retort must also be luted with care.

The simplest lute that can be employed for this purpose, is paper spread with paste or slips of moistened bladder, with which the junctures are covered: but this lute is liable to become soft by the contact of the vapours; it may easily be corroded, so that it is only used as a preparation for other lutes which are laid on over it.

The lute known by the appellation of the *fat lute*, is the best of all. It not only adheres strongly to glass, and resists the effort of vapours, but also withstands the corrosion of acid vapours. It is made of boiled linseed oil, beat up in an iron mortar with finely-sifted clay,

till it becomes of such a consistence as to be easily moulded with the hand. To use it, you roll small cylindrical pieces between your fingers, and apply them to the junctures. When you have closed all the apertures, you bind on the lute with slips of paper spread with paste, or, what is still better, of linen covered with lute of lime and white of egg. The last mentioned lute is made by mixing a small quantity of very fine quick-lime with white of egg, and beating up this mixture with a spatula. Spread it immediately on pieces of old rag with the spatula, and apply it to the junctures. This lute soon dries, adheres strongly to the glass, and opposes an invincible resistance to the effort of the vapours.

When you lute with paper or bladder, you must suffer the apparatus to dry; otherwise the first vapours remove the lute, and it is impossible to confine those which succeed.

In operations on a large scale, the junctures are secured with the same lute as is employed for the retorts: a very thick coat is applied, which becomes hard with heat, and resists the effort of the vapours.

These were the limits of our means of con-

ducting a distillation, and of condensing vapours, before modern chemistry taught us that, in almost all distillations, there was an escape of gaseous incoercible matters, by which the chemist was frequently incommoded, which he let out from time to time by opening the tubulure of the receiver; but which it was of considerable importance to repress and retain.

Woulf was the first that contrived an apparatus adapted to this purpose: many improvements have since been made on the invention of that able chemist; and I shall now proceed to describe it, such as it is at present employed in our laboratories.

If we examine the nature of the volatile substances which rise in distillation, we shall find that some soon lose the caloric which vapourises them; that others cannot be condensed unless we present to them some liquid with which they may combine or dissolve; and that there is a third kind, which invariably retains its aëriform state, when we have once broken by heat the bonds which held it in a state of combination.

In the first case, a simple receiver is sufficient to produce condensation. In the second, the

vapour, or gas, must be made to pass through the liquid which is to absorb it. In the third, vessels full of water may be presented to the incoercible substance; so that, as fast as they receive this gas, they empty themselves of the liquid which they contain. *Fig.* 1, in *Plate* VIII, will convey a more accurate idea of this apparatus.

Between the receiver and the trough, *ll*, filled with water, place three bottles, each with three necks. Then adapt the curved tubes, *ssss*, to the orifice of the receiver, and to two of the necks of each bottle. The extremity of the last tube opens under a vase reversed in the trough.

The second branch of each tube descends to a considerable depth into the bottles, while the other is open at the upper end.

To the middle neck of each bottle is likewise adapted a tube which descends to a considerable depth, and opens into the air by a cup or funnel at the upper end.

To the middle of the curvature of the tubes *ss* at the two ends, has likewise been adapted a pipe with a protuberance in the middle of its length.

Each tube is passed through a cork *oood*, that it may exactly fit the neck of each bottle. The corks are prepared for the reception of the tubes by being pierced with a round sharp-pointed red-hot iron.

This done, pour through the funnels *xxx* the water or liquid proper to combine with or to dissolve the gas that is disengaged; and as you know the quantity of liquid necessary to saturate the volume of gas which ought to be disengaged from a given quantity of matter subjected to distillation, divide it between the first and second bottle; reserve the liquid of the third, which cannot saturate itself for a second operation, and then place it first. The liquid poured into each bottle should cover the ends of the tubes *pp*, and the longest branch of the tubes *sss*. At the same time a small quantity of water is made to run into the little balls *qq*.

It is now evident that, if any vapour escapes from the receiver, it must be conveyed into the liquid of the first bottle through the end of the first tube which opens there; that in traversing this volume of liquid it must be combined or dissolved; that the portion which is

not absorbed will rise to the surface, escape by the second tube, and pass into the liquid of the second bottle, thence to the third, and lastly from the third to the vase *m*, into which it will rise, displacing at the same time the water which is suspended there.

The distillation being finished, you will find, 1. in the receiver, the substances easily coercible, &c.; 2. in the bottles, the gaseous substances susceptible of combination, or of solution in water; 3. in the vase, the incoercible gases.

But, as the heat has dilated the aëriform substances contained in the receiver and the bottles, there would be reason to apprehend, lest the cooling of the apparatus, or the diminution of the disengagement of gas, might produce a pressure on the part of the exterior air, that would drive the water in the trough into the third bottle, which would empty itself into the second, the second into the first, and the first into the receiver. This inconvenience in Woulf's apparatus has been obviated by M. Melther's contrivance of *tubes of safety xxxx*: for it is evident that the external air must rush through these tubes, and soon restore the equi-

librium, whenever the smallest vacuum begins to take place in the vessels. As the tubes are plunged into the liquid in the bottles, and those which are fastened to the curvatures have some water in the ball *qq*, it is impossible for the vapours, which are disengaged by distillation, to escape into the air.

The operation of distilling may be performed in the same apparatus on a sand-bath, as represented in *Plate* VIII. *fig.* 2.

The apparatus described above is one of the greatest improvements that could have been introduced in our laboratories. It not only affords us a medium of collecting all the products of a distillation, but also enables us to obtain them separately; it removes all fear of any explosion in a laboratory, and prevents the volatilisation of any acrid, pungent, or dangerous substance, which alike incommode the artist.

This apparatus is now known in our large manufactories; it is used for the preparation of muriatic acid, ammonia, &c.

Distillation is one of the operations most frequently performed in chemical laboratories. It is employed to separate the constituent principles of a body, almost always susceptible of

volatilisation at different degrees of heat; and to collect the gaseous substances, which are detached from their combinations by re-agents possessing a stronger affinity for their base. The analysis of vegetable and animal matters by the retort furnishes us with an application of the first case: the decomposition of muriate of ammonia with lime, or muriate of soda with sulphuric acid, affords an example of the second. We shall make a few observations on the distillation of plants, in order to present an application of the principles which we have laid down.

The distillation of plants was almost the only method of vegetable analysis practised before the middle of the last century. But the uniformity of the products obtained from almost all vegetables might have sufficed to produce a conviction that this method was defective. Caloric, which enters as a principle into distillation, gives a new form, and imparts a peculiar character to the substances with which it combines. As it first separates the most elastic principles it destroys the nature of the compounds to which they belonged; it forms new combinations by detaching and bringing into

action matters possessing the same degree of volatility, and which escape at the same time; so that it produces water, acids, and ammonia, which did not exist in the vegetable. In a word, the products of the distillation of a plant no longer exhibit the nature and organic state of the vegetable, any more than the ruins of a conflagration represent the design after which the consumed structure was erected. In either case you find nothing but the disorder of decomposition, and a mixture of some primitive principles preserved in their original nature, with many others which have been altered, and with various substances of new formation. But these products, whether secondary or primitive, afford qualities of which human ingenuity has availed itself; and it is this that renders distillation a highly interesting operation for the arts. It is by its means that we extract volatile oils, the odoriferous principle, or aroma, distilled waters, pyroligneous acid, hydrogen gas, &c.

But, as most of these operations are performed on a large scale, and as some form distinct arts in society, such as those of the perfumer and distiller, larger vessels than retorts are em-

ployed, and alembics, of which we now proceed to treat, are made use of in their stead.

ARTICLE II.

Distillation with the Alembic.

The *alembic* is a kind of metal retort, to the neck of which is adapted a long, spiral tube, fixed in a tub full of water to produce the condensation of the vapours.

Though the alembic is employed to extract the odorous principle of various substances, as well as the volatile oils of plants, yet we shall apply the principles of distillation to that of wines, which is, doubtless, the most interesting of any. The amendments which we propose in this apparatus for distillation, may be applied to all the purposes for which the alembic can possibly be employed.

The alembics that were used at the remote period, when the distillation of wines first began to be practised, were boilers with a long,

cylindrical neck, narrow, and fitted into a hollow hemisphere, from which a tube of no great width conveyed the liquid into the worm.

Arnauld de Villeneuve seems to have been the first person in France that gave his countrymen precise notions relative to the distillation of wines; and to him they were indebted for the first description of that kind of alembic with a very long neck, patterns of which may still be found in the shops of perfumers.

The idea that the produce of the distillation was the finer, purer, and more subtle, the higher it was raised by causing it to pass through narrow tubes, led to the construction of these vessels for distilling; but it was not long before alterations were made in the apparatus. It was imagined, that the art of graduating the fire, rather than the obstacles opposed to the ascension of the vapours, rendered the produce of the distillation more or less pure.

But at the period when chemistry began to survey the operations of the arts with more judicious eye, it was thought that still more

advantageous alterations might be made in this distilling apparatus.

The form of the boiler was judged too high and not sufficiently wide; for as the fire acts only on its base, the distillation proceeds slowly; and the deposit, formed during the evaporation, receiving a too violent degree of heat, contracts a disagreeable taste of fire which is communicated to the spirit.

The contraction of the upper part of the boiler seemed to oppose the free ascent of the vapours. It was thought, that as this part of the boiler was not covered with brick-work, and was exposed to the atmospheric air, the temperature must be cooler there than in the other points, and consequently the portion of the column of vapour which touched the sides must become cooled, condensed, and fall back into the boiler. It was imagined, that this uncovered part of the boiler might be compared to the portion of the retort, which, in distillation by the sand-bath, is not covered with sand; and as it is observed that, in this case, the liquid which rises in vapours is partly condensed, and running in drops down the sides, falls back into the mass, it was concluded that

a similar phenomenon must take place in the distillation of wines, when it is performed in the apparatus we have described.

Baumé compared the contraction of the upper part of the boiler in the old apparatus to a kind of éolipile, through which the vapours cannot pass without effort, and which, as he asserts, requires the employment of a more considerable force of ascension.

It has likewise been contended, that, as the head is also exposed to the temperature of the external air, the latter could not fail to produce there likewise all the inconveniences that have already been noticed in treating of the contraction of the upper part of the boiler.

The method of disposing the fire appeared still more defective. The boiler being fixed over the fire-place, the heat directly strikes against the surface of the bottom alone; so that the current of air which enters at the door rushes into the chimney, passing between the burning fuel and the bottom of the boiler.

It is evident that this construction must be extremely faulty, that great part of the heat is lost in the chimney, and that the heat which is applied to the liquid, only at one single point,

must be but slowly communicated to the whole mass.

The observation of these defects in the form of boilers, and in the construction of the furnace, caused the following improvements to be proposed and adopted.

The heighth of the boiler has been considerably diminished; the width has been augmented, and the sides have been sloped in such a manner, that the diameter progressively increases to about three or four inches from the top; there the sides are curved into an arch, and become narrower, so that the mouth of the boiler is exactly of the same diameter as the bottom. *See Plate* IX. *fig.* 1.

To the boiler is fitted a conical head, in the interior of which, round the lower edge, is a gutter, destined to receive the liquid condensed against the sides, and which, instead of returning to the boiler, is conveyed into the worm, of which we shall presently treat.

The head is surrounded with a refrigerator, intended to hold cold water, for the purpose of condensing the vapours which strike against the interior surface of the head.

In the old construction, the head communi-

cated with the worm by an inclined tube of a very small diameter; but, in the improved apparatus which we are describing, the tube of communication is at its base as high and as wide as the head, and diminishes in diameter as it approaches the worm into which it opens, and is adjusted.

The worm differs in no respect from the old one, except that the first circumvolutions are larger. *Plate* IX. *fig.* 2.

We must not omit noticing the improvement which has been made in the bottom of the boiler. Instead of being flat, it is now curved in such a manner as to be convex within. This form renders the heat nearly equal in every point; the bottom of the boiler is stronger, and cannot be so easily pressed down by the liquid; the deposits which are formed during the evaporation, are thrown to the angles which rest upon the brick-work; they do not receive the direct heat, and are, consequently, less liable to be burned.

Besides these changes, more or less advantageous, that have been made in the alembic, particular attention has been bestowed on the improvement of the fire-place; and it is prin-

cipally to the ameliorations effected in this department of distillation that we are indebted for the advantages derived from the new process.

We have already observed, that the old construction of the furnace permitted the heat to be applied directly to no other part but the bottom of the boiler. The current of air which entered at the door of the fire-place hurried along with rapidity the flame and the heat given out by the combustible, and carried them into the chimney after brushing, and, if I may so express myself, licking the bottom of the boiler. This construction occasioned the loss of nine-tenths of the heat produced by the fuel; the distillation was much more tedious, and the produce of inferior quality; because, the mass of the liquor being heated only in one point, it was necessary that the heat should be kept up there, and of sufficient strength to communicate to the whole mass. Consequently the deposits which were formed could not escape being burned, and this produced an empyreumatic taste.

Instead of this faulty construction the following was adopted. Supposing you have to

fix a boiler two feet in diameter at the base, and three in the broadest part over a furnace, you first trace a square of five feet each way, and raise brick walls on three of the sides, making on the fourth an arch, which forms the roof of the ash-pit. This arch must be two feet above the ground, and extend to the depth of two feet and a half into the square. The centre of the air must be eight inches thick, and upon this is fixed the door of the fire-place.

In the upper part of the arch, and at the depth of fifteen inches from the front of the furnace, is left an aperture of a foot square. This aperture receives the grate which supports the fuel. Between the bars of the grate there must be a sufficient space to allow the ashes and small coal to fall into the ash-pit, and to afford a constant passage to the air necessary for the combustion.

From this construction it is apparent that the grate is not placed in the middle of the furnace, but that it is quite in the front; so that when the boiler is fixed in the middle, the end of the grate next to the chimney corresponds with the middle of the boiler.

When wood is employed for fuel, there is no occasion for an ash-pit: the air then enters at the door, and the combustion is more gentle. The ash-pit and the fire-place are then one and the same.

When the grate is placed, fix one leg of the compasses in the middle of the bottom of the grate, and describe a circle twenty inches in diameter, supposing, as we have already observed, that the boiler is two feet in diameter at the base.

On the outside of this circle erect a circular wall, or rather continue to raise the square of brick-work that forms the base of the furnace, taking care to arch that part which corresponds with the door of the fire-place. Let this part be twelve or fifteen inches high, according as the combustible to be employed produces more or less flame.

In the part opposite to the door of the fire-place, and a little to the right, form in the circular wall a slope, six inches wide and ten deep, which serves for the aperture into the chimney.

On this brick-work is placed the bottom of the boiler, cementing it with care, that there

may be no passage or communication between the exterior and interior of the furnace. From these dispositions it is obvious, that two inches in the whole circumference of the bottom of the boiler must rest upon the brick-work.

The boiler being thus fixed, build a circular wall all round it, at the distance of eight inches from the lower edge of the boiler. Raise the wall in a perpendicular direction to the level of the largest diameter: there connect the brick-work with the boiler, and cover the whole upper part of the latter which recedes, to the base of the circle which forms the orifice. It should likewise be observed here, that this circular vacancy about the boiler is interrupted by a partition wall that is erected on one side of the aperture which issues from the fire-place, and commences the spiral flue; so that the current which escapes from the fire-place and rushes into this flue that winds round the boiler would not find any egress, unless care were taken to make one behind the party-wall above-mentioned. Thus this current, after turning round the boiler, and heating circularly the whole mass of the liquid, escapes by the aperture which forms the base of the straight

or perpendicular chimney, as may be seen by a reference to *plate* IX. *fig.* 4. The perpendicular chimney may be eight or ten inches square.

Such are the improvements which have been progressively made in the art of distillation. I may venture to assert, that I have myself contributed considerably to bring it to the present degree of perfection; but after proposing and executing these ameliorations with the greatest advantage, I have satisfied myself that the excellence of the process essentially depends on the judicious alterations which have been made in the construction of the furnace, I have found that the advantage ascribed to the refrigerator, and also the idea of the pressure of the vapours, and their supposed efforts to rise and force their way through the neck of the boiler, were rather the result of theory than a fact established by experience. I have therefore suppressed the refrigerator, and have merely formed a wide communication between the head and the worm, taking the whole heighth and width of the head to form the base of the tube which is adapted to the first cir-

cumvolution of the worm. The suppression of the refrigerator has the advantage of diminishing the expence, and simplifying the apparatus.

This suppression of the refrigerator, which I adopted so long since as the year 1800, and this return to the old construction of the heads of alembics demonstrate how easy it is to err when we take theory or mere reasoning for our guide

Every thing that relates to the distillation of wines may be confined or reduced to two principles:

1. To communicate an equal heat to all the parts of the mass of the liquid, and to apply to them all the heat which is disengaged by combustion.

2. To condense expeditiously and entirely all the vapours which arise.

The construction of the furnace produces the first effect.

The disposition of the grate throws the fire-place under the anterior half of the diameter of the boiler, so that this part receives the direct action of the heat of the fire-place; and as the

current of air always tends to carry the flame and the heat toward the chimney, it strikes in its passage against the other part of the bottom of the boiler.

This same current then rushes into the spiral flue, and applies itself to the whole lateral surface of the boiler where it spends its heat; so that the liquid is enveloped with all the heat that is disengaged from the combustible.

The form of the boiler greatly facilitates the action of the fire. Exclusive of the advantages which have already been mentioned, the concavity of its bottom contributes to augment the effect of the heat by applying it to a larger surface.

To produce the second effect, or to condense expeditiously and completely the vapours which pass into the worm, nothing more is necessary than to keep cold water around it. For this purpose fresh supplies of water are made to enter at the bottom of the worm, and the heated water is drawn off from the top.

When it is possible to have a constant current, the water always keeps at a cool temperature, and the spirit exhales scarcely any smell, because it is highly condensed.

Some have endeavoured to avail themselves of the heat produced by the vapours of the spirit, by receiving them into a worm for which wine serves as a refrigerating liquid: they have even covered the worm with a head to collect the spirit which rises in vapours, and to carry it by means of a pipe into the circumvolutions of the worm. But these methods, though ingenious, have not received the sanction of daily practice, and it is difficult to appreciate their utility.

The distillation of wines has recently received new degrees of improvement, and such are the advantages of these new processes, that the old establishments are no longer able to maintain a competition with those which are formed on the modern principles. These processes are still kept secret by their authors; but as various artists contend for the discovery, and have formed distilleries on the same principles, I think myself at liberty to publish as much concerning them as has come to my knowledge.

The new apparatus for distilling is a genuine Woulf's apparatus. It consists of a cauldron fixed in a furnace, and a series of circular boilers which communicate with each other by means

of pipes. The apparatus is terminated by a worm.

Wine is put into the cauldron, and into all the intermediate vessels between it and the worm. The neck attached to the head of the cauldron plunges into the liquor in the first vessel to the depth of ten or twelve inches.

From the empty part of this first vessel runs a pipe, which plunges into the liquor of the second vessel to the same depth as the first.

From the second issues another pipe that is adapted to the worm, which is cooled by the process we have described.

When the wine contained in the cauldron is heated, the vapours which rise from it pass over into the liquid in the first vessel, and communicate to it a sufficient degree of heat to disengage from it the spirit of wine. These vapours of spirit of wine pass into the liquid of the second vessel, and effect the volatilisation of the alcohol which it contains. Thus one moderate fire occasions the ebullition of a prodigious quantity of wine, distributed in several vessels: and the condensation of this large mass of vapours takes place, as usual, in the worm.

You may obtain spirit of greater or less strength, and procure, at pleasure, any degree of spirituosity you wish, by taking the produce of the first receiver or of the second.

If, instead of employing wine you put water into the cauldron, and wine into the other vessels, you obtain a milder and more pleasant spirit than when you put wine into it. There is scarcely any occasion to observe that the water in the cauldron must be replaced as fast as it decreases by evaporation, unless you calculate and determine the quantity requisite to complete the evaporation of all the alcohol contained in the wine to be distilled.

In the contrary case it is easy to replace, by a very simple contrivance, the portion of the liquid which evaporates from the cauldron, without suspending or retarding the distillation.

This process is attended with the two-fold advantage of considerably diminishing the expence of fuel, since it is applied only to a small vessel in proportion to the mass of liquid which is evaporated, and of extracting more spirit from a given quantity of wine, than by the ordinary apparatus.

The improvements successively made in the process of distillation have produced spirits infinitely more mild than those obtained by the old processes. The latter have an empyreumatic, or burnt taste, but the consumers, especially in the north of France, were so accustomed to it, that for some time they refused to drink the milder and more pleasant tasted spirits, so that the distillers were obliged to render them empyreumatic by the admixture of burnt spirits, in order to suite their taste.

Wines furnish more or less spirit, according to their degree of spirituosity: a very generous wine yields one-third of its weight of spirit. In Languedoc the average produce is one-fourth; the wines of Bourdeaux yield one-fifth, and those of Burgundy not so much.

The spirit extracted from old is of better quality than that obtained from new wines. Saccharine wines furnish an excellect spirit.

Sour wines yield a spirit of very bad quality, on account of the great quantity of malic acid, which is almost inseparable from them.

By diluting the husks of pressed grapes with water, and proceeding to distillation, you

obtain a further portion of spirit, but it is of bad quality.

In distilling for the purpose of extracting spirits, you continue the operation till no more spirit of wine passes over, or till the produce ceases to be inflammable.

The distiller forms a judgement of the degree of spirituosity of the liquor which is distilling, by the number and size of the bubbles produced by agitating the liquor, and by the longer or shorter time of their duration. For this purpose, he either pours it from one glass into another, letting it fall from a considerable height, or he fills a long bottle two-thirds full, and stopping it with his thumb, he shakes and strikes it with force against the hollow of his hand to form bubbles.

Various methods for determining the strength of spirits have been successively tried and practised.

The regulation made in France in 1729 directed that some gunpowder should be put into a spoon, that it should be covered with the spirit intended to be proved, and then set fire to.

A judgment was formed of the strength of the spirit according as the flame burned or did

not burn the gunpowder; but the same spirit inflames or does not inflame, according to the proportion in which it is used; a small quantity always takes fire, a great quantity never does, because the water retained by the residue of the combustion, is sufficient to wet the powder and to preserve it from inflammation.

Carbonate of potash has also been employed, as dissolving with more or less facility, according to the quantity of water contained in the spirit.

The Spanish government in 1770 prescribed the use of oil for proving spirits. The process consists in letting fall a drop of the oil into the spirit; a judgment is formed of its degree of spirituosity from the greater or less depth to which the drop of oil descends in the liquor.

In 1772 Messrs. Poujet and Borie of Cette turned their attention to this subject, and obtained results which have furnished commerce with a spirit-gage of such accuracy, as not to produce the least error in the estimates which are daily made with it.

After having made very nice experiments on the proportions of water and alcohol, and on the action of the temperature on the mixture,

at every possible degree, they adapted the thermometer to the spirit-gage, and transferred to a scale the comparative progress of the real spirituosity, together with the effects of the temperature, so that their spirit-gage itself indicates the alterations made by the temperature. This instrument is now the only one employed in commerce in the south of France.

The use of such an instrument is so necessary in commerce, that for more than fifteen years I have seen the dealers of the south purchase Spanish spirits, which varied in the degree of spirituosity, and take no further trouble than to raise or reduce them to the degree of commerce, merely by adding either spirit of wine or water, in order to obtain an advantageous sale.

The produce of the distillation of wine is ...lled in France *Hollands proof spirits.*

...if you again subject this spirit to distil-...you then obtain a more spiritous liquor, ...s called *three-fifths.* In this case three ...f the liquor, mixed with two parts of ...ater, form five parts of spirits; *Hollands*

...With the spirit-gage of Messrs. Borie and

Poujet the different degrees of spirituosity are very easily ascertained by means of silver weights of various sizes: the heaviest is inscribed with the words, *Hollands proof*, and the lightest *three-sevenths*. The other weights serve to mark the intermediate degrees between these two terms. Thus if you screw to the end of the beam of the spirit-gage the weight denoting *Hollands proof*, and plunge it into *three-fifths*, the instrument will descend in the liquid below the degree marked on the scale Hollands proof, but it returns to that point on the addition of two-fifths of water; so that *three-fifths* spirit is thus transformed into *Hollands proof spirit*.

If, on the contrary, you screw on the *three-fifths* weight, and plunge the spirit-gage into *Hollands proof*, it will rise in the liquor above the latter mark, and it may be easily carried down to that degree by the addition of alcohol, or spirit of wine.

When spirits are distilled for the purpose of extracting alcohol, or spirit of wine, the *balneum mariæ* is generally employed. The heat is then more gentle and more equal, and the

produce of the distillation of superior quality.

Alcohol, or spirit of wine, is used as a beverage. It is the dissolvent of resins, and constitutes the basis of drying varnishes.

Spirit of wine serves as a vehicle for the aromatic principle of plants, and is then called spirit of this or that plant.

The apothecary likewise employs spirit of wine to dissolve resinous medicines. These dissolutions are denominated *tinctures*.

It forms the base of almost all the different sorts of beverage called *liqueurs*. It is sweetened with sugar, or rendered aromatic with all kinds of substances of an agreeable taste or smell.

Spirit of wine preserves vegetable and animal substances from fermentation or putrefaction. To this end it is used for preserving fruits, vegetables, and almost all the objects and preparations relating to the natural history of animals.

All the liquors produced by the fermentation of saccharine substances, yield alcohol. But the quantity and quality vary according to the nature of the substances.

Spirit distilled from cyder has a very disagreeable taste, on account of the abundance of mucilage which it contains; but if great care be taken in the distillation, an excellent spirit may be obtained.

The spirit extracted from cherry wine is denominated *kirschenwasser* (cherry water) that made from syrups of sugar or molasses, is called *rum*.

Pallas has seen fermented malt liquor distilled near Pinbirsk, for the purpose of extracting spirit. To this end the people there use alembics with heads made of wood, and necks which communicate with a pipe constantly kept cool with cold water.

The same naturalist relates, that the Calmucks leave cows' and mares' milk to become sour in vessels of leather or other substances. They assist the acetification with heat, and with a leaven made of coarse flour and salt, or with the rennet of lamb's stomachs. They do not skim the milk which is intended to furnish spirit. They distil the milk when quite sour in boilers covered with a wooden head, and collect the produce in vessels which they

keep cool by putting them into snow or very cold water.

Spirits are distilled from corn in almost every region of the globe, but they are bad, and to disguise the disagreeable taste, they are distilled with juniper berries. These are known by the name of *geneva*, or *gin*.

SECTION VIII.

Results of the Action of Heat, applied at different Degrees to various Mineral Substances.

Men, in all ages, have been sensible of the importance of ascertaining the effect of heat at different, and accurately determined degrees on all bodies; and we find in almost every work the results of numerous experiments made on this subject. But not possessing the means of having a constant, equal, and very elevated heat, and besides the system of analysis not be-

ing sufficiently advanced to permit the chemist to operate on pure matters, or such as were constantly of the same nature; the facts which have been handed down to us are not fit objects of comparison, so that they are rendered totally useless to science.

It is of little importance to know that a stone found in the Alps or Pyrenees is fusible or not fusible. But it is essentially interesting to ascertain by accurate experiments,

1. The manner in which every pure earth and every metal is effected by a known degree of heat.

2. The action or effect of the same degree of heat on simple substances, when they are mixed together in known proportions.

3. The effect of fluxes on the same substances.

When results of this nature are well authenticated they are serviceable at all times, and in all places, and the arts may rely upon them as positive facts.

I conceived that it would be useful to collect into a table the principal experiments on fusion, which present the above-mentioned characters.

To this end I have selected from an infinite number of experiments, such of the results as are capable of instructing and guiding artists in the operations which have for their object the action of fire on bodies that are best known and most employed.

Darcet was one of the first chemists that essayed the action of an equal, long-continued, and comparable heat on a great number of bodies. His experiments were made in 1766 and 1768, in porcelain furnaces, in which the heat was maintained at the same degree of intensity for several days.

Lavoisier and Ehrmann essayed almost all known bodies with the blow-pipe, and with a current of oxygen gas.

M. de Saussure made numerous experiments with the flame of the simple blow-pipe.

Macquer subjected a great number of mineral substances to the action of the burning glass.

Messrs. Guyton, Morveau, and Kirwan have likewise employed determinate degrees of heat to ascertain the fusibility of various simple and compound substances.

From the works of these distinguished natural philosophers we have extracted the results that compose the annexed table.

From an inspection of this table, it will easily be perceived that the results of the experiments made by different chemists do not always correspond. The reason of this is, that the substances employed were not always exactly of the same nature, or that the crucibles or stands reacted upon them. But as mixtures are, in general, more fusible than pure matters, we cannot but conclude that we have not operated on a simple substance whenever we obtain the fusion of a body, which other experiments indicate to be absolutely infusible.

This table may still be thought very imperfect; but as my only object was to shew the action of fire on the mineral substances most generally employed in the arts, and the most extensively diffused in nature, I thought fit to confine the tables within those limits.

Names of substances.	Porcelain fire.	Blow-pipe and atmospheric air.	Burning-glass.	Blow-pipe and oxygen gas.
Platina.	The grains of platina became united; the mass turned black, like iron scales. By pounding, a black and highly attractable powder may be detached. The remainder, again submitted to the fire, loses the property of being attractable. Platina exposed to the same fire, in crucibles of porcelain, does not melt or lose its brilliancy, and becomes more attractable. (*Darcet*)	The grains of platina are not in the least altered. (*Bergmann.*)	Platina exposed to the focus of Tschirnhausen's burning-glass, at length agglutinates; but in the numerous experiments made in 1772 and 1773 by the academicians of Paris, it could not be melted. Parker's burning-glass melted it in less than two minutes. (*Kirwan.*)	Crude platina undergoes a complete fusion, and the metal divides into round globules, if the quantity does not exceed 5 or 6 grains. Platina, purged of its magnetic sand, exhibits the same phenomena as crude platina. (*Lavoisier.*)
Gold.	38½ grains of gold from a guinea, exposed thrice to the fire in porcelain crucibles, lost half a grain the first, and nothing the second time.	Melts on the coal, and remains there without alteration. (*Bergmann.*) M. de Saussure says, that it disappears, and is entirely dissipated in smoke.	Homberg and Macquer melted and volatilised it with Tschirnhausen's burning-glass. The latter even perceived a stratum of violet-coloured oxyd.	Gold easily melts; and Lavoisier gilded a piece of silver, by holding it over the gold in fusion.
Silver.	One pennyweight, 13 grs. of copelled silver, lost 8 grs. in porcelain crucibles. A portion of oxyd attacks the interior of the crucibles, and forms a spongy coat of a pale yellowish white. Silver, if vapourised, breaks the crucibles.	Cupelled silver unites into globules, and turns into vapour.	A portion of the metal is vapourised without oxydizing; an infinite number of small globules are thrown upon the stand.	It melts in 10 seconds, and turns to vapour without taking fire. When the heat is kept up without vaporising, the metal becomes oxydized; but it is easily reduced, and afterwards evaporates. (*Ehrmann.*)

Names of substances.	Porcelain fire.	Blow-pipe and atmospheric air.	Burning-glass.	Blow-pipe and oxygen gas.
Copper.	It melts, and becomes oxydized. It formed a mass of a beautiful red in a porcelain crucible.	It melts on cyanite, and covers it with a brilliant black varnish, colours the exterior flame green, and is entirely evaporated. The cyanite remains white and pure.	Exposed to the focus of the burning-glass on a stone stand, it passes into the state of oxyd.	It was melted in 13 seconds; it bubbles, emits a green flame, and is entirely volatilised. (*Lavoisier, Ehrmann.*)
Tin.	It is oxydized, and becomes green. Sometimes it is converted into a gold yellow glass, extremely beautiful and transparent.	The fibre of cyanite being charged with filings of Malacca tin, and suddenly introduced into the middle of the flame, the filings are partly dissipated in sparks; the exterior flame is tinged with a light purple. A thin stratum of yellowish glass remains upon the cyanite; but if the exterior flame be made to approach the filings, the tin becomes oxydized. This oxyd does not melt; it appears, on the contrary, to be evaporated, and entirely dissipated. Under this oxyd, the cyanite seems tinged with yellow.	It melts into a white globule, shining like silver, from which rises a white, abundant, clear, and luminous smoke. If taken from the fire, there remains a vitreous, opaque, hard, and brittle matter, covered with small needles. The tin is at length entirely volatilised.	It instantly melts, bubbles, and becomes red. A white, thick smoke, accompanied with a white flame, ascends from it. The metal becomes oxydized. (*Lavoisier.*) Ehrmann observed a blue flame; he adds, that one grain of tin is volatilised in 30 or 40 seconds.

Names of substances.	Porcelain fire.	Blow-pipe and atmospheric air.	Burning-glass.	Blow-pipe and oxygen gas.
Lead.	It forms a yellow and transparent glass.	It tinges the exterior flame blue; it turns to transparent glass of a greenish yellow, and evaporates, leaving behind a yellow tint.	Minium is converted into a beautiful, brilliant litharge, without reduction. White lead melts instantaneously, emitting much smoke. One portion is converted into litharge the other vitrifies the stone stand.	It immediately melts, and emits a reddish smoke with flame. If exposed slowly to the fire, it becomes oxydized. This oxyd afterwards melts and evaporates; and when the heat is increased the matter burns with a white flame. (*Lavoisier*)
Iron.	Iron became oxydized, and formed a mixture with the paste of the porcelain.	It enters into fusion, bubbles, and sparkles; then penetrates between the fibres of the cyanite, which it colours a bright, then a dull black, and afterwards a transparent bottle green, which at last becomes clear.	It burns in the fire, and produces brilliant tufts. (*Hamberg.*)	It melts, becomes red, and burns, emitting small stars, which are scattered like a shower of stars. These particles, when united, are small, hollow, and brittle balls.
Zinc.	It melts and inflames, producing much flaky oxyd.	It melts, takes fire, and produces a white, woolly oxyd.	It melts, becomes covered with white oxyd. It takes fire when this covering of oxyd is removed.	It melts, becomes red, and burns. The flame is red towards the middle, and blue at the point. It emits a great quantity of flaky oxyd.

Names of substances.	Porcelain fire.	Blow-pipe and atmospheric air.	Burning-glass.	Blow-pipe and oxygen gas.
Bismuth.	It runs, and is converted into glass of a pale, transparent violet, the colour of clear wine-lees.	The filings laid upon the piece of cyanite, and slowly advanced to the flame, crack, sparkle, gives a violet tint to the exterior flame, and a yellowish smoke, which adheres to the surrounding objects, and is converted into a greenish yellow glass, which grows darker, and afterwards evaporates gradually, leaving a pale, purplish tint, and some indications of corrosion.		It burns with a whitish flame, which soon becomes yellow. The metal swells, flies out of the crucible, and makes yellow or brown spots on whatever it touches. One grain may be volatised in 15 seconds. (*Ehrmann.*)
Cobalt.	Darcet calcined and melted it into an opaque and dark blue mass.	Enters into fusion; and if the fire is kept up, but not too strong, at length forms a dark violet mass.	Ditto.	Becomes red, melts, and burns, with a blueish flame, approaching to violet. Some sparks escape from the crucible.
Arsenic.	It attacks and softens the paste of porcelain.	It inflames when suddenly exposed to the fire. (*Bergmann.*)		It burns with a light blue flame, and is dissipated, at the same time emitting a smell of garlic.

ARTICLE II.

Table of the Action of Heat on certain compound Substances.

Names of substances.	Porcelain fire.	Blow-pipe and atmospheric air.	Burning-glass.	Blow-pipe and oxygen gas.
Sulphate of lime.	Crystallized gypsum of Montmartre produces a beautiful transparent glass. This glass penetrates and dissolves the crucibles. Striated, or silky gypsum exhibits the same phenomena.	Crystallized gypsum of Montmatre exfoliates, becomes white, and melts into a snow white paste. On the cyanite it bubbles a little, becomes semi-transparent, penetrates, and corrodes.	Gypsum of Montmartre, calcined and wetted, and first gently warmed out of the focus, smoked a little, then being submitted to the focus, after shrinking considerably, it opened in several places, and at length melted into a matter which formed milk-white masses, semi-transparent, like porcelain. (*Macquer.*	Very pure gypsum of Montmartre, previously calcined, bubbled and melted. (*Lavoisier.*) Ehrmann melted all the gypsums on which he operated.

N. B. Gerard observed, that the gypsums become more solid in crucibles of chalk or coal, whereas they vitrify in those of argil. It appears, as Lavoisier has asserted, that, when the fire has been able to volatilise all the sulphuric acid, then the residue, being infusible, is liable to deceive the operator in various experiments tried upon that sulphate.

Names of substances.	Porcelain fire.	Blow-pipe and atmospheric air.	Burning-glass.	Blow-pipe and oxygen gas.
Fluate of lime.	Fluates of lime melt at a degree of heat more or less violent, according to their purity. The glass is more or less coloured; it assails the crucible, which it corrodes and dissolves.	Octagonal, transparent, greenish fluor spar forms cauliflowers, of a dull, opaque, snow-white. On the cyanite a fragment melted into a very transparent, colourless glass. (*Saussure.*)	Cubic fluor spar of the Vosges, and the same spar coloured did not melt in the focus of Tschirnhausen's burning-glass on a stone stand: but they formed a round fluid globule, which, as it cooled, became of an enamel white. (*Lavoisier.*)	Fluor spar of the Vosges melted into a glass, clear and transparent as water. The globule, as it grew cold, became opaque; it had no longer the glassy polish of spar; but resembled a melted salt, and easily crumbled to powder. (*Lavoisier.*)
Sulphate of barytes.	This stone melted in a porcelain fire; it assails the crucibles, which it covers with a coating of glass, like the fusible spars.	Ponderous, transparent, colourless spar, decrepitates, tinges the exterior flame green, and when melted is of a dull, and almost opaque white. On the cyanite, after having tinged the flame green, it melts into a transparent, yellowish glass, which corrodes slowly, and without efferves-cence. (*Saussure.*)	The ponderous spar of Sainte Marie aux Mines, exposed to the focus of Tschirnhausen's burning-glass, on a stone stand, calcined without fusion; but being put into a concavity in the coal, it underwent a kind of combustion, emitted sulphureous vapours, and left a lime which retained the taste of sulphur of alkali. (*Lavoisier.*)	The ponderous spar of Sainte Marie Mines, of the most beautiful opaque white and lamellated structure, burns with detonation. It leaves on the coal a white, acrid, and bitter coating, with a taste of sulphur of alkali. The analysis of it proved it to be sulphur of barytes. (*Lavoisier.*)

We are indebted to Messrs. Darcet, Ehrman, Guyton, Morveau, Kirwan, and other chemists, for very interesting experiments on the manner in which the mixtures of certain primary matters constantly employed in the same proportions, are affected by various determined degrees of heat. I think it useful to give a statement of their results in this place; they will be of service to all those who are engaged in pyrotechnical operations.

1. *Darcet's Experiments with the Porcelain Furnace.*

Mixtures.	Results.
a. Equal parts of quartz and slaked lime.	An unconnected matter.
b. Equal measures of very hard spar and slaked lime.	Melted, and formed a vitreous, opaque mass.
c. Equal measures of fine gypsum and slaked lime of marble.	Opaque glass.
d. Equal measures of fine gypsum and white argillaceous earth.	White, semi-transparent enamel.

Mixtures.	Results.
e. Three measures of fine gypsum, and one of washed kaolin.	Hard, white, opaque, glass, forming a beautiful enamel.
f. Equal measures of gypsum and gun-flint.	A very hard, solid mass, striking fire with a steel.
g. Two measures of plaster, and one of fusible spar.	A beautiful semi-transparent glass.
h. Equal measures of fine gypsum and Never's sand.	A beautiful semi-transparent glass.
i. Eight measures of Never's sand, and a fusible spar.	A hard solid mass. Semi-transparent enamel.
l. Eight meaures of fusible spar, and two of Briançon chalk.	Glass imperfectly melted.
m. One measure of gun-flint, two measures of fusible spar, three measures of fine gypsum.	Opaque glass, of a milk-white.
n. Equal measures of fine gypsum, pure argil, and hard spar.	Opaque glass, very solid; good enamel.
o. Equal measures of fine gypsum, soft spar, and Champagne chalk.	A spongy, opaque, white matter.
p. Fine gypsum, soft spar, one measure of each; Champagne chalk two measures.	Opaque glass, of a yellowish green.

Mixtures.	Results.
q. Equal measures of plaster, pure argil, and Champagne chalk.	Glass, half transparent, of a beautiful white.
r. Equal measures of fine gypsum, pure argil, and flints.	Glass of a light green, approaching to yellow, and transparent.

M. Guyton Morveau tried the action of two degrees of heat, the lowest of which was from twenty-three to twenty-eight degrees, and the highest one hundred and thirty-four degrees, of Wedgwood's scale, on various earthy mixtures.

For the first blast the crucibles were placed under the muffle of the cupelling furnace.

For the second they were exposed under a reversed crucible in Macquer's furnace.

Composition.	Results of the first fire.	Results of the second fire.
Alumine 1 gram. Magnesia 1 gram.	A white matter, slightly agglutinated, separating between the fingers; lost 0,135 of its weight.	A white, pulverulent matter; and vitrification at the point of contact with the crucible.
Silica 1 gram. Magnesia 1 gram.	White pulverulent lost only 0,108 of its weight.	A white matter, slightly agglutinated; lost 0,135.
Silica 1 gram. Barytes 1 gram.	A mass neither solid, nor adhering to the crucible, of a grey colour. Lost 0,01 of its weight.	Glass of a greenish grey, with a cellular appearance, very hard, so that nothing but rock crystal could scratch it.
Alumine 1 gram. Barytes 1 gram.	Slightly agglutinated, of a bluish grey, not adhering to the crucible; lost 0,105 of its weight.	A white, pulverulent matter, lost 0,275 of its weight.
Lime 1 gram. Magnesia 1 gram.	The mixture remained white, without any sign of combination, and without any sensible loss.	A matter white at the surface, reddish underneath. The lower part vitreous, semi-transparent, and containing bubbles. The bottom of the crucible perceptibly assailed, and covered with a white, semi-transparent enamel, likewise containing bubbles.
Lime 1 gram. Barytes 1 gram.	A white, pulverulent matter. Slightly agglutinated at the surface, without loss of weight.	Perfect glass rather greenish, which cracked when withdrawn from the fire, and adhered to the sides of the crucible.
Magnesia 1 gram. Barytes 1 gram.	A matter sensibly agglutinated.	White, shining, united, in clotted and very solid particles, some of which, in the state of enamel, adhered strongly to the sides of the crucible.

Ehrmann subjected various metallic mixtures to the action of oxygen gas, which presented the following results:

Mixtures in equal parts.	Results.
1. Gold and platina	An alloy of a dull, silver white, very ductile under the hammer.
2. Gold and copper	Fusion accompanied with a green flame, which continued till the whole button was volatilised. Gold, silver, and copper, melted together, exhibit the same phenomena.
3. Platina and silver.....	An alloy, harder and darker than silver. It beat cold under the hammer.
4. Platina and copper	A whitish alloy, capable of being hammered, flattened, and polished.
5. Platina and iron	These two metals combine very imperfectly; they seem at first to unite, but separate as they grow cold.
6. Platina and antimony.....	This mixture, previously fused in the crucible, and exposed to the current of oxygen, separates; the antimony burning with a white flame, and exhaling into the air.

Mixtures of equal parts.	Results.
7. Silver and copper	Melts immediately, and emits a green flame. The mass is entirely volatilised, if the fire is kept up.
8. Copper and tin	As soon as the mixture is in fusion, the tin burns with a whitish flame, surrounded with an almost imperceptible blue colour, but which increases more and more in proportion as the tin diminishes.
9. Copper and iron	These metals do not combine. The copper places itself in the centre, and the iron remains in a crust, which is soon burned.

Erhmann made experiments on the following mixtures, employing the metals in various proportions.

1. Alloy of copper and zinc, forming brass.	It first crackles, and burns with a light blue flame, which changes to dark blue.
2. Alloy of lead and antimony, forming printing types.	Emitted a very strong vapour. The flame is light blue.

M. Kirwan has given us, in the second edition of his *Elements of Mineralogy*, a table of the fusibility of simple earths, mixed in various proportions, and exposed to a fire not exceeding one hundred and sixty-six degrees of Wedgwood's thermometer. M. Achard has also published the results of a long series of experiments on the same subject. But it is probable, that the fusions which he obtained were frequently owing to the substance of his crucibles which were exposed to the long continued fire of a porcelain furnace. M. Kirwan conceives that he avoided, in a great measure, that source of errors, by employing the fire of a good forge, which was much stronger, but not so long kept up. M. Achard composed his mixtures with aërated lime. M. Kirwan used quick lime, which yielded very different products. The principal results which he deduces from his researches, and those of M. Achard, are the following:

Binary Combinations.

1. The binary combinations of the five earths (lime, magnesia, alumine, silica, and

barytes) are infusible, be the proportions of the mixtures what they may, except in two cases: 1. The mixture in equal parts of lime and silica, which merely forms an enamel at a heat exceeding one hundred and fifty degrees of Wedgwood; 2. The mixture of barytes and silex. These two substances do not act upon each other at a heat exceeding one hundred and fifty degrees, unless the silex be to the barytes in the proportion of three to one, or of two to one, or unless the barytes be to the silex in the proportion of four to three, or of two to one; but the reciprocal action of these two earths is scarcely perceptible when their quantities are equal.

2. In the mixture of the five earths with oxyd of iron, it is observed, that that in which quick lime is to oxyd of iron in the proportion of nine to one, or of three to one, or of two to one, becomes a kind of paste at a heat of one hundred and fifty degrees, and attacks the crucible. It becomes very fusible if the proportion of oxyd of iron be increased.

Barytes and oxyd of iron have a much more evident reciprocal action when the mixture is

made up of equal parts; but when the oxyd of iron is to the magnesia in the proportion of four to one, the mixture is completely melted. The fusion is imperfect when the two substances are in the ratio of two to one.

Alumine and oxyd of iron exhibit no appearance of fusion at a heat of one hundred and sixty-six degrees, even when the two substances are mixed in equal parts; but when the oxyd of iron is to the alumine either in the proportion of four to three, or two to one, the mixtures are fusible at the same degree of heat. Silica and oxyd of iron appear infusible when the silica is in excess; but in the contrary case their mixture is fusible.

Ternary Combinations at One Hundred and Fifty Degrees of Wedgwood.

Lime, Magnesia, and Alumine.

1. The mixtures of these three earths, in which magnesia predominates, are never fusi-

ble below the one hundred and sixtieth degree of Wedgwood.

2. The mixture in which lime predominates does not vitrify unless it be composed in the proportions of three parts of lime, two of magnesia, and one of alumine. The proportions which nearly approach these are capable of producing a kind of porcelain or enamel.

3. The proportions in which the quantity of enamel is equal to that of the two others, and exceeds one of the two in the proportion of three to one, are capable of forming porcelains.

Lime, Magnesia, and Silica.

1. The mixtures in which the lime is in excess are fusible.

2. If the magnesia be in excess, no mixture can be fusible.

3. If the silica be in excess, the mixtures will very rarely be fusible.

Alumine, Magnesia, and Silica:

1. If the alumine is in excess, you can obtain nothing but a porcelain.

2. If the magnesia is in excess, you cannot obtain even an imperfect fusion.

3. If the silica is in excess, you may in most cases obtain a porcelain, and a glass under this circumstance, namely, when the earths are in the proportion of three parts of silica, two of magnesia, and one of alumine.

Alumine, Lime, and Silica.

1. If the lime is in excess, you obtain a glass, or a porcelain, or an infusible mass, according to the proportions of the mixture.

2. If the alumine is in excess, you may obtain in most cases a porcelain, but never a glass.

3. If the silica is in excess, you may fre-

quently obtain an enamel or a porcelain, and probably also a glass, for the heat given in these experiments was not considerable.

SECTION IX.

Methods of measuring Heat.

In the operations by fire, of which we have been treating, it is of great importance to be able to determine the degree of heat with which you operate, for this is the sole method of comparing the results of our experiments, and rendering them useful to others.

The appellation of *thermometer* has been given to the instruments which are employed to measure the atmospheric heat, or that which is not very elevated; and the instrument designed to measure the degrees of heat in our fire-places, and in the furnaces of the arts, is known by the name of *pyrometer*.

All these instruments are founded on the

principle that heat dilates all bodies; in order, therefore, to ascertain the respective degrees of heat, nothing more is necessary than to determine those of dilatation.

Mercury and alcohol have been employed for making thermometers; their change of volume is perceptible upon the slightest change of temperature. To produce this change of volume, and to be able thence to deduce the alteration of temperature, it has been found sufficient to inclose those liquids in a narrow glass tube, correctly graduated. Mercury deserves to be preferred to alcohol, because it presents a very long and invariable scale of degrees of dilatation constantly proportioned to the degrees of heat, whereas alcohol does not observe the same progression, except at a low temperature.

These two liquids enclosed in glass tubes can only measure the degrees of heat inferior to the degree of fusion of glass itself, and to the degree of their vaporisation. It has therefore been found necessary to resort to other means for the purpose of measuring elevated degrees of heat. Boerhaave and Muschenbroeck pro-

posed pyrometers founded on the dilatation of iron by heat; but the pyrometer which has hitherto proved most deserving of the attention of chemists is Wedgwood's. It is constructed on the principle, that the purest argil is contracted in proportion to the heat which is applied to it.*

This pyrometer is composed of two parts: 1. Of a *gage* which serves to measure the degrees of heat; 2. Of small pieces of argil, which are employed to take the degree of heat by the contraction which they undergo. The gage is formed of a cake of baked earth, upon which are placed two rulers of the same substance. These rulers, which are perfectly straight and smooth, are distant three tenths of an inch at one of the ends, and half an inch at

* This phenomenon seems to contradict the principle we have laid down, that all bodies are dilated by caloric. It is, however, nothing but an apparent contradiction, because the contraction of the argil is occasioned only by its yielding up a portion of the water which adheres to it so closely, that the utmost degree of heat is required to vaporise it entirely.

the other. This ruler is divided into two hundred and forty equal parts, each of which measures one tenth of an inch.

To form the pieces for a thermometer, the earth is sifted with the greatest care: it is then mixed with water, and this paste is made to pass through an iron tube, which gives it the form of long sticks, that are cut into small cylinders of a suitable length. When the pieces are dry they are presented to the gage, and ought to adapt themselves to zero of the scale. If any piece is one or two degrees longer, the number of those degrees is marked at the bottom, and must be deducted when this piece is employed for measuring heat. The pieces thus arranged are baked in a furnace with a red heat to give them the consistence necessary for their removal from place to place. The heat employed in this operation is generally six degrees; but it is of little importance if they are to be submitted to a very superior heat. If by accident you want to measure an inferior, then make use of unbaked pieces.

When you design to use this pyrometer, expose one of the pieces in the furnace whose

heat you are desirous of measuring, and when you judge that it has experienced the utmost intensity of the heat, take it out and let it cool. Then present it to the gage; slide it along between the two rulers till it will go no further; the degree of heat it has undergone is calculated from the contraction which has taken place.

Mr. Wedgwood has himself given a table of some of the corresponding degrees of his pyrometer with those of Fahrenheit's thermometer.

	Wedgwood.	Fahrenheit.
1. Red heat visible by day-light -	0	1077
2. Swedish copper melts - - -	27	4587
3. Pure silver melts - - - -	28	4717
4. Pure gold melts - - - - -	32	5237
5. Welding heat of iron - - -	least 90	12777
6. Greatest heat of a common smith's forge - - - - -	greatest 95	13427
	125	17327
7. Cast iron melts - - - -	130	17977
8. Greatest heat of an air-furnace eight inches square - -	160	21877

Wedgwood's pyrometer is attended with this inconvenience, that it does not produce effects essentially comparable, because it is impossible to make it with an earth invariably of the same nature in different parts of the globe. This led M. Guyton to propose a pyrometer of platina, of which he has given a description in the Annales de Chimie.* It is composed of a rod of platina simply laid in a groove made in a cake of refractory clay, and baked in the highest degree of heat. This rod rests at one end on the edge which terminates the groove, and at the other on a lever with two arms, the larger of which forms a needle on a graduated arc of a circle; so that the removal of this needle, from its position, marks the additional length which the metal acquires by the heat.

All the parts of this instrument being of platina, no apprehensions need to be entertained either of fusion or oxydation.

But it cannot have escaped the observation of any of my readers, that the various apparatus

* Vol. XLVI. page 276.

designed to ascertain the degree of heat, do not measure the quantity that may be contained in a body, which, however, it is of great importance in many cases to know. To remedy this great defect, or to fill up this chasm in the science of pyrometry, Messrs. Laplace and Lavoisier contrived an apparatus capable of determining the total quantity of caloric which may be disengaged from a body, till its temperature be reduced to that of ice. They give to it the appellation of *calorimeter*, and it is founded on the principle that ice absorbs heat, without communicating any till it is melted.

In order to obtain correct results, it was necessary: 1. To discover the means of causing all the heat that is disengaged from a body to be absorbed by ice; 2. To skreen the ice from action of any other substance that may cote to melt it; 3. To collect all the water duced by its fusion.

The apparatus constructed for this purpose the two celebrated academicians, consists of circular bodies, fixed nearly one in the , so as to produce three vacancies (*Plate* A. *fig.* 1 & 2.) The interior vacancy *eee*

(fig. 2.) is formed of iron wire-work, supported by props of the same metal. In this space are put the bodies submitted to experiment; it is covered with a top likewise formed of wire-work. The middle vacancy *bhbb (fig. 2.)* is designed to contain the ice which is placed all round the inside. The ice is supported and kept at the bottom by very close wire-work. This space is separated from the inner one only by the grating. As the ice melts the water runs through the wire-work into the cavity *ee (fig. 2.)* and is received in the vase *e (fig. 1.)* when the cock *d (fig. 2.)* is opened. The outer space *aaaa*, contains the ice which envelopes the middle one, and prevents the access of the external heat. The water formed in this cavity escapes by the pipe *hh (fig. 2.)* and runs into a distinct vessel. This space is separated from the middle one by a partition of tin or copper, so that there is no communication between them.

In order to use this ingenious apparatus, the middle space and the covering of the interior sphere are filled with pounded ice. The exterior space is filled with the same substance,

which is also spread over the general cover of the whole machine. Drain the interior ice; do the same with that in the outer space, and in the general covering of the whole machine *gg (fig.* 1.)

When the interior ice ceases to furnish any water, take off the cover to introduce the body, and put it on again immediately. Collect with care all the water that runs off, till the temperature of the body be reduced to that of the ice. It is evident that the weight of the water obtained affords the exact measure of the heat disengaged from the body, which alone occasions the fusion.

It is necessary that the heat of the atmosphere should not be below zero, because then the interior ice would receive a degree of cold under that point.

The specific heat being nothing more than the proportion between the quantity of heat necessary to raise to the same number of degrees, the temperature of bodies equal in mass, it follows, that to obtain the specific caloric of a solid body, you must elevate its temperature to any number of degrees, place it quickly in the

interior sphere, and leave it there till its temperature has fallen to zero. Collect the water, and its quantity, divided by the product of the mass of the body, and the number of degrees which its primitive temperature was above zero, will give the proportion of the specific heat.

To ascertain the heat of fluids enclose the vessels in the calorimeter, in order to reduce the heat to the temperature of ice, and then quickly pour off the liquids.

To determine the heat of respiration, and of gaseous matters, form a communication by means of tubes between the interior sphere, and the external body which contains the air subjected to experiment, and you may establish a circulation between the exterior and interior, which is kept up till the air under experiment ceases to melt the ice. The quantity of heat given out by the air on its passage may be estimated by holding two thermometers to the two orifices for ingress and egress.

END OF VOL. I.

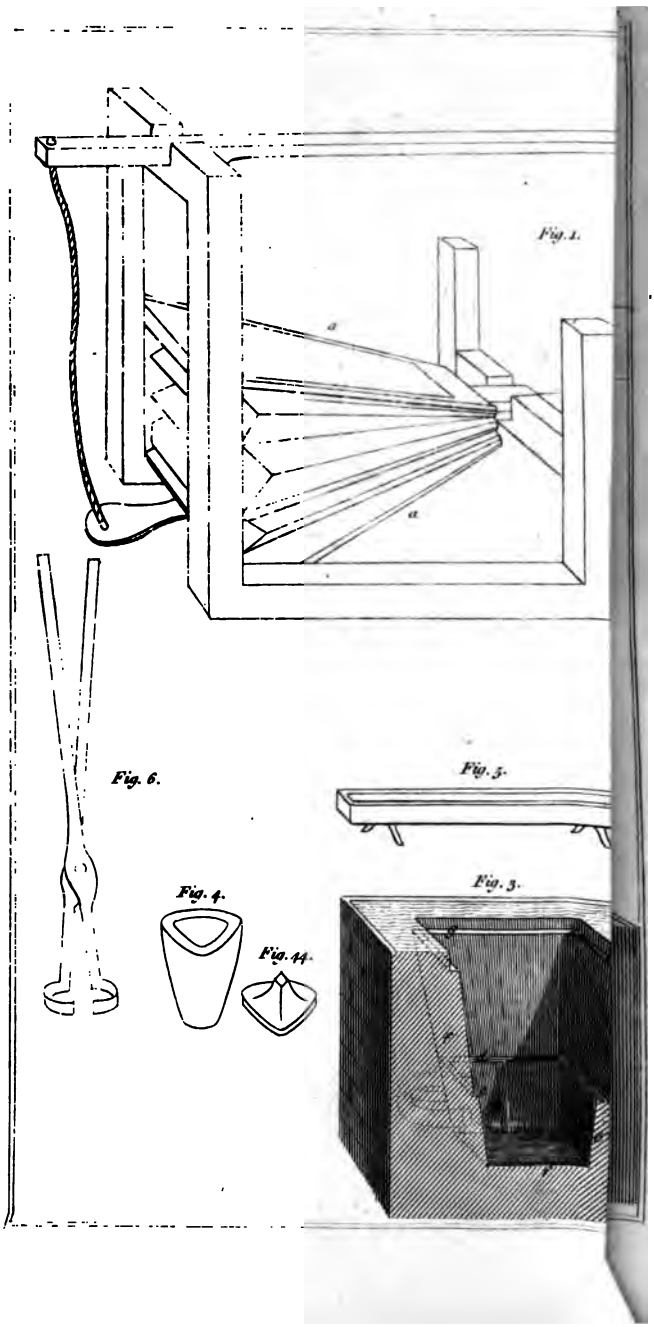


Fig. 1.
a
a
Fig. 6.
Fig. 5.
Fig. 4.
Fig. 44.
Fig. 3.

EXPLANATION OF THE PLATES

IN THE FIRST VOLUME.

PLATE I.

Figure 1, represents the forge of a laboratory with its bellows.

aa. The bellows.
bb. The forge.
c. The support of the forge.
d. The fire-place.
e. The dome.
f. The chimney.
g. The door of the dome.

Figure 2, represents a laboratory forge with a triple current of air.

aa. Bellows with a double pipe.

bb. Reservoir of air.

ccc. Tubes which convey the air to the forge.

dddd. Square forge.

e. Interior of the forge.

ff. Contraction of the forge to receive the cover.

gggg. Thickness and sides of the forge.

22. The cover of the forge.

222. The grate.

Figure 3, represents the section of the forge with a triple current of air.

ccc. Apertures by which the air of the three tubes passes into the forge.

ee. Bottom, or floor of the forge.

dd. Contraction of the forge to receive the grate.

gg. Upper contraction to receive the cover.

ffff. Thickness of the sides of the forge.

Figure 4, represents a crucible.

44. The lid of a crucible.

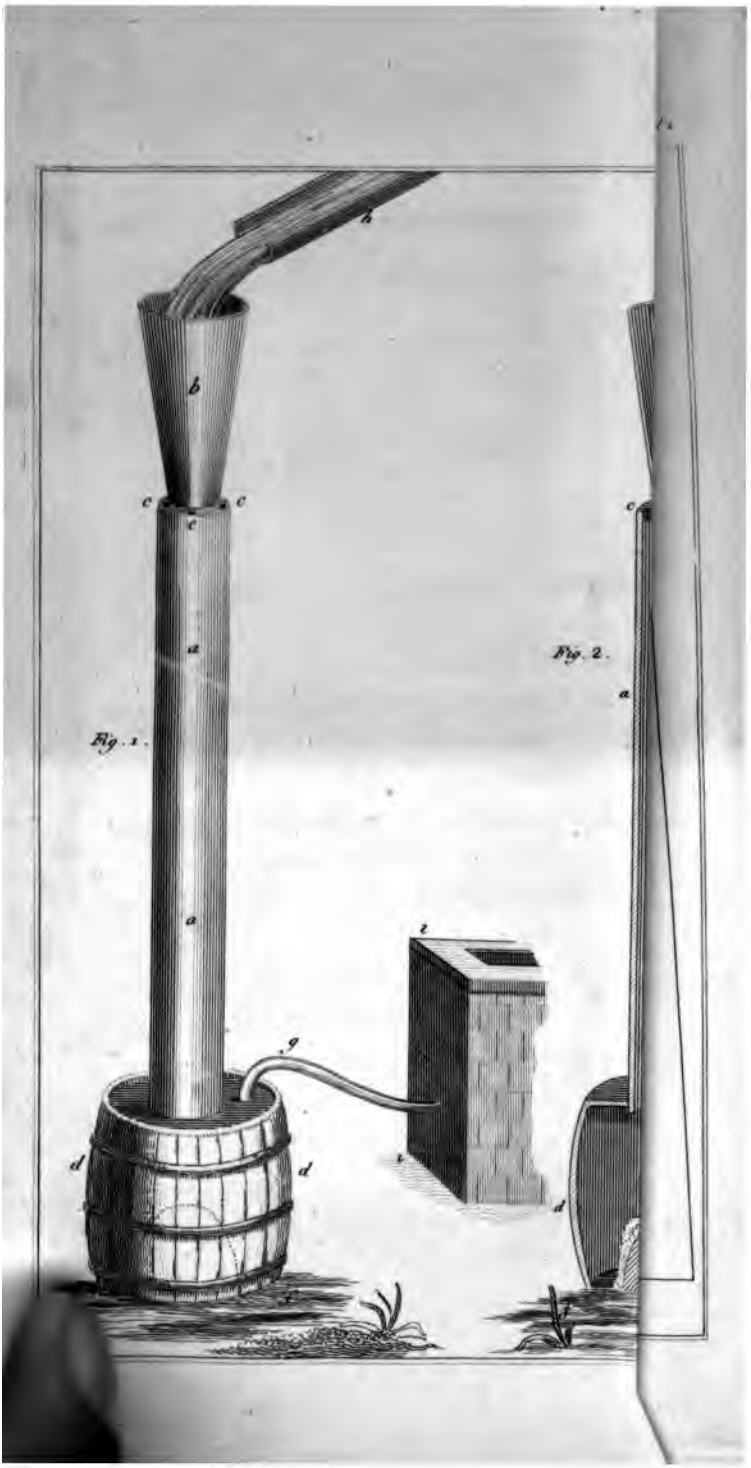

h
b
c
c
c
a
a
Fig. 1.
Fig. 2.
c
a
i
g
d
d
d
d
k

Figure 5, represents an ingot-mould.

Figure 6, represents a pair of tongs for crucibles.

PLATE II.

Figure 1, exhibits a view of a trunk.

aa. The cylinder.

b. The portion of the cylinder hollowed out into the form of a funnel.

ccc. Three air holes.

dd. The cask, with the head knocked out and placed in water.

e. A conical stone fixed in the middle of the cask.

ff. A current of water which dashes against the lower part of the cask.

g. The tube which conveys the air into the furnace.

h. A current of water which runs into the cylinder.

ii. The furnace to which the air is conveyed.

Figure 2, represents a vertical section of a trunk.

aa. Longitudinal section of the cylinder.
b. Funnel at the top of the cylinder.
cc. Two lateral air-holes.
dd. The cask with the head knocked out.
e. The conical stone placed in the middle of the cask.
ff. The current of water in which the lower part of the cask is plunged.
g. The tube which conveys the air into the furnace.
h. The current of water which discharges itself into the cylinder.

Figure 3, represents the plan of a furnace for melting iron ore, at the height of the bellows.

Figure 4, represents a section of the same furnace.

c. Fig. 3 & 4. Aperture for the bellows.
d. Fig. 3. Aperture for the discharge of

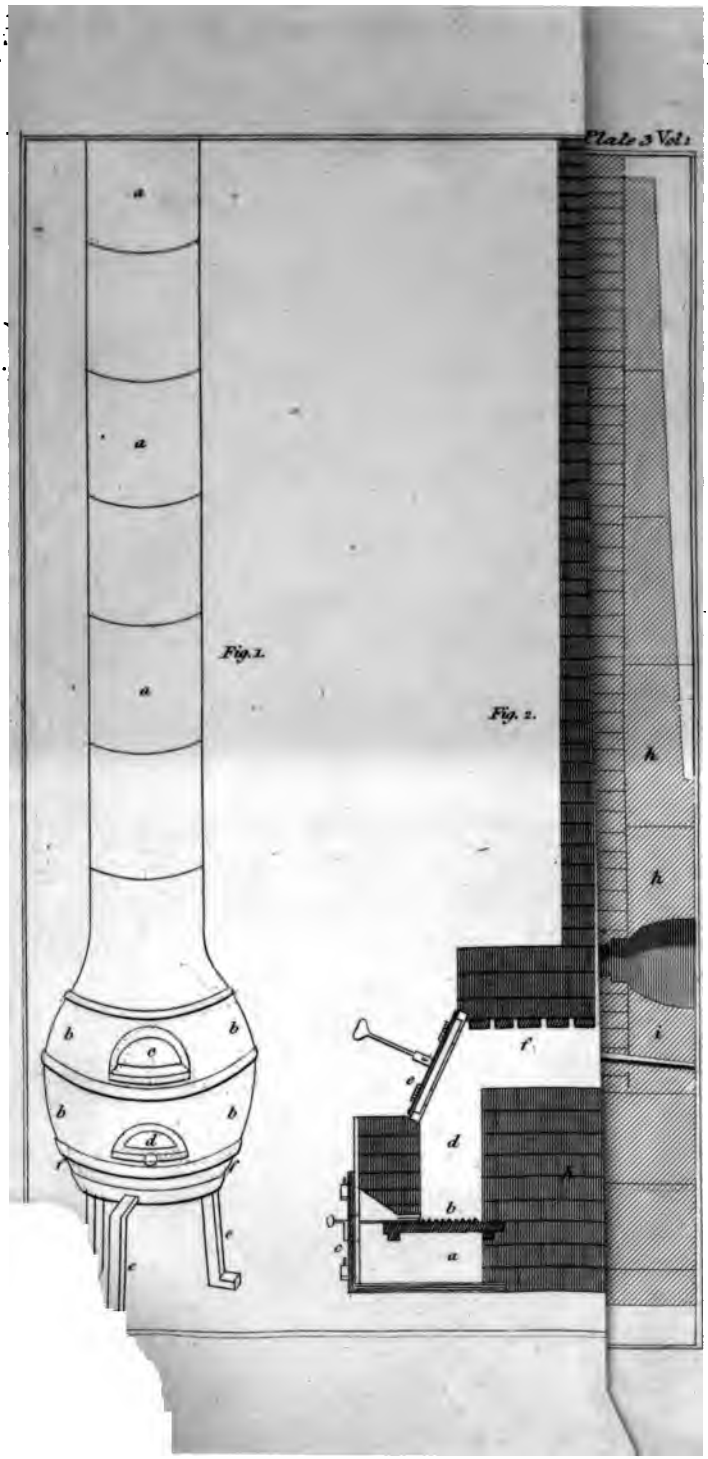


Plate 3 Vol:
a
a
a
Fig. 1.
b
b
c
b
b
d
f
f
e
e
c
Fig. 2.
f
e
d
b
c
a
h
h
i

the melted metal.

ef. Fig. 4. Interior height of the furnace.

gg. Fig. 4. Greatest height of the furnace.

This furnace is circular from *i* to *k*; the remainder is square.

PLATE III.

Figure 1, represents the smelting furnace of a laboratory.

aaaa. The chimney.

bb. The fire-place.

c. The door of the fire-place.

d. Lower door of the fire-place, to judge of the state of the crucible.

eee. Trevet on which the furnace stands.

ff. Grate of the furnace.

Figure 2, represents a wind-furnace.

a. The ash-pit.

b. A moveable grate.

c. The door of the ash-pit.

d. The fire-place.

f. The floor.
g. The chimney.
h. Masonry.
i. The wall against which the furnace is fixed.

Figure 3, represents a smelting furnace with a free current.

a. Steps to go down to the ash-pit.
b. The ash-pit.
cc. Grate of the fire-place.
dd. The floor or laboratory.
ee. The chimney.
f. Masonry.
gg. Dome of the laboratory, of brick-work.
hh. Exterior wall of the chimney.
i. Melted matter

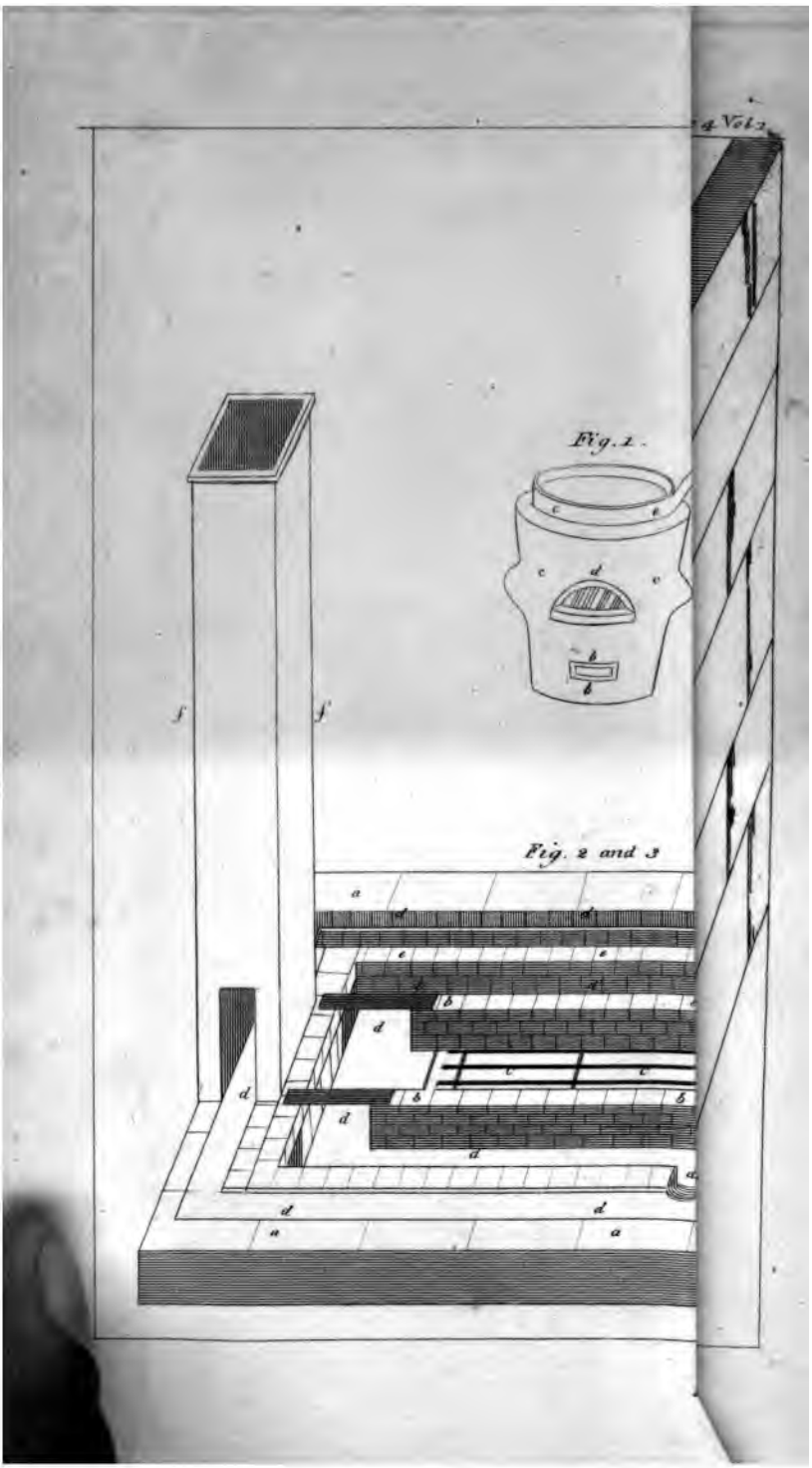


Fig. 1.
Fig. 2 and 3

PLATE IV.

Figure 1, represents an evaporating furnace.

aa. The ash-pit.
bb. The door of the ash-pit.
cc. The fire-place.
dd. Door of the fire-place.
ee. The evaporating vessel.

Figures 2 & 3, represent a furnace with flues winding under and round the sides of the boiler.

aa. Masonry in which the furnace is fixed.
bb. Brick walls erected on the sides of the grate, and upon which the boiler is placed.
cc. Grate of the furnace.
dddd. Conduit or current of heat which passes under the boiler, and round the sides into the perpendicular chimney.

eeee. Walls parallel to the walls *bb,* separating the lower chimney from the lateral one, and upon which the boiler rests.

ff. Perpendicular chimney opposite the fire-place.

gg. Anterior part of the furnace.

Figure 4, represents a vertical section of a furnace, with spiral flues under and round the sides of the boiler.

aa. Masonry inclosing the boiler.

bb. Section of the ash-pit.

cc. Section of the fire-place.

dddd. Walls supporting the boiler, and separating the fire-place from the lower part of the chimney, and the chimney from the lateral flue.

ee. The chimney, or flue underneath the boiler.

ff. The lateral flues.

g. The boiler.

Figure 5, is the view of a boiler fixed upon its furnace, with its chimney against the wall, above the fire-place.

Fig. 3.
g
g
a
a
a
a
c
c
c
A
b
b
a

PLATE V.

Figure 1, represents the vertical section of a round boiler and spiral flues.

aaaa. Square of brick-work in which the boiler is fixed.
bb. Section of the grate.
cc. Ledge on which the boiler rests.
dd. Masonry against the bottom of the boiler.
ee. Spiral flue.
ff. Beginning of the spiral flue.
gg. Beginning of the perpendicular chimney.
hh. The boiler marked by dotted lines.

Figure 2, represents the furnace of a round boiler, with a spiral flue, and the chimney over the door of the fire-place.

aaa. Masonry in which the furnace is fixed.
bb. Door of the fire-place.

cc. Legs on which the furnace stands.
dd. Ledge which supports the boiler.
ee. Beginning of the spiral flue.
ff. The spiral flue.
gg. The perpendicular chimney.

Figure 3, represents the furnace of a round boiler, with a spiral flue, and a perpendicular chimney opposite to the door of the fire-place.

aaaa. Brick-work in which the furnace is fixed.
bb. Door of the fire-place.
cc. Legs on which the furnace stands.
dd. Ledge supporting the boiler.
ee. Beginning of the spiral flue.
ff. The spiral flue.
gg. Perpendicular chimney.
hh. The wall which separates the beginning of the spiral flue from the perpendicular chimney, and obliges the current of heat to pass quite round the boiler before it escapes by the perpendicular chimney.

Vol. 2.

Fig. 1

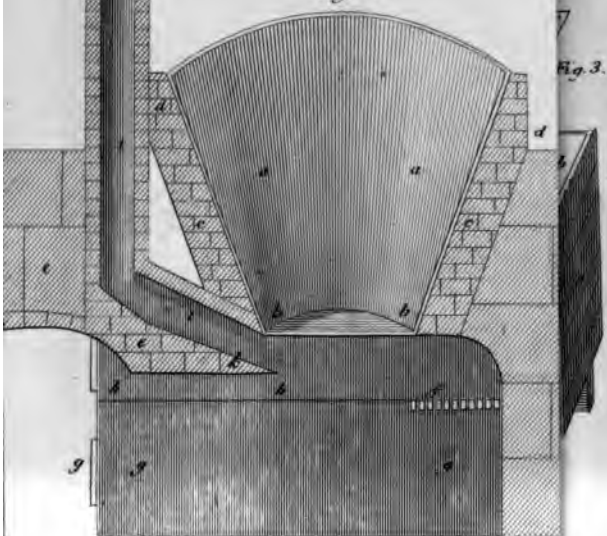


Fig. 3.

Fig. 4.

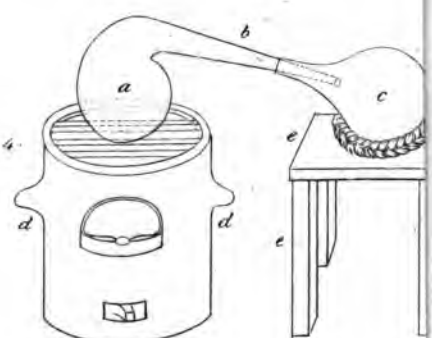


PLATE VI.

Figure 1, represents the vertical section of the furnace of a soap-house.

aa. Boiler in which the soap is boiled.

bb. Copper bottom of the boiler, the sides being of masonry.

cc. Brick walls forming the sides of the boiler.

dd. Brick walls projecting beyond the masonry *ee*, and inclosing the upper part of the boiler.

eee. Masonry of free stone.

f. Grate of the fire-place.

ggg. Ash-pit.

hh. Passage of the fire-place.

ii. Chimney.

k. Prolongation of the wall separating the chimney from the passage of the fire-place.

Figure 2, represents the vertical section of a boiler with a convex bottom, fixed upon its furnace.

aa. Section of the boiler.
bb. Convex bottom of the boiler.
cc. Circumference of the bottom resting upon masonry.
d. Section of the grate.
eee. Roof of the ash-pit.
ff. Spiral flue.
ggg. Masonry of the furnace.

Figure 3, represents the process of evaporation with the naked fire.

aa. Boiler or pot set upon the fire-place of a furnace.
bbb. Lateral apertures producing a current of air.
cc. Door of the fire-place.
dd. Bottom of the fire-place.
eee. Masonry of the furnace.
ff. Supports of the furnace.

Figure 4, represents a retort on the fire with its receiver.

a. Body of the retort.
b. Neck of the retort.
c. The receiver.
dd. Furnace.
ee. The stand of the receiver.

Figure 5, represents evaporation with the sand-bath.

aa. The furnace.
b. Door of the fire-place.
c. Door of the ash-pit.
dd. Vessel containing sand, placed on the furnace.
ee. Evaporating vessel, placed on the sand.
ff. Sand contained in the vessel *dd.*

Figure 6, represents evaporation by the balnea-mariæ.

aa. Boiler in which the balnea-mariæ is fixed.

bbbb. Balnea-mariæ marked by dots in the inside of the boiler, and by lines on the outside.

cc. Handles of the boiler.

dd. Handles of the balnea-mariæ.

ee. Aperture of the balnea mariæ.

PLATE VII.

Figure 1, represents a reverberatory furnace for the purpose of distillation.

aa. Ash-pit and fire-place.

bb. Laboratory of the furnace.

cc. Dome, or reverberating roof of the furnace.

dd. Chimney.

ee. Door of the ash-pit.

ff. Door of the fire-place.

Fig. 6.

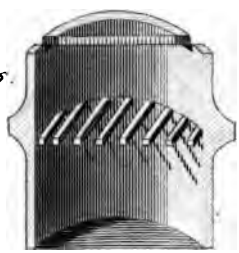
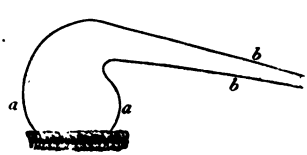
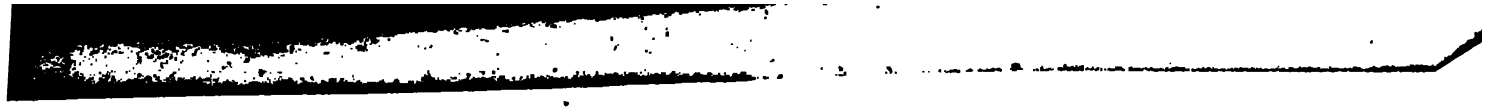


Fig. 2.





gg. Support, or handles of the laboratory.

h. Aperture to admit the neck of the retort.

ii. Handles of the dome.

k. Receiver.

ll. Stand of the receiver.

mm. Retort represented in the laboratory by dotted lines.

Figure 2, represents a retort.

aa. Body of the retort.

bb. Neck of the retort.

Figure 3, represents a tubulated retort.

aa. Body of the retort.

bb. Neck of the retort.

cc. Tubulure of the retort.

Figure 4, represents a tubulated receiver.

Figure 5, represents an adapter.

Figure 6, represents a vertical section of the fire-place and ash-pit of a reverberatory furnace.

PLATE VIII.

Figure 1, represents distillation with the pneumato-chemical apparatus.

aa. Ash-pit.
bb. Door of the ash-pit.
cc. Fire-place.
d. Door of the fire-place.
ee. Laboratory.
f. Retort, represented by dotted lines.
gg. Hole for the neck of the retort.
hh. Receiver.
i. Door of the dome.
kk. Beginning of the chimney.

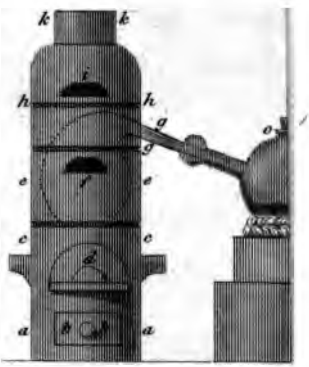
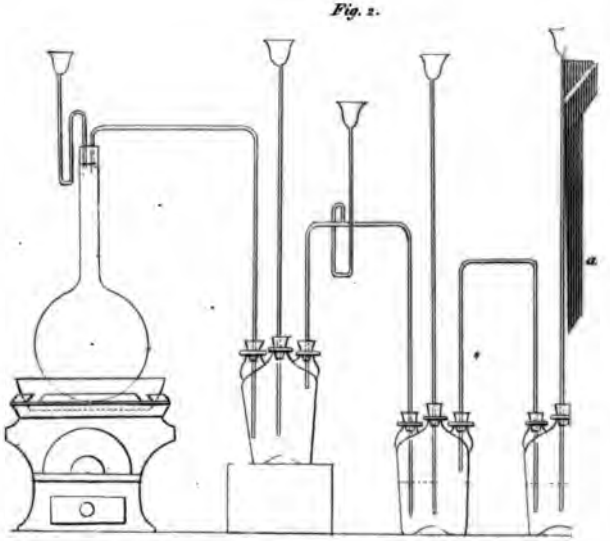


Fig. 2.



ll. Part of the hydro-pneumatic trough filled with water.

m. Vessel inverted on the trough, and full of water.

nn. Height to which the liquid, put into the bottles, rises.

ooo. Tubulure of the receiver and of the bottles.

pp. Depth to which the tubes *x* descend into the liquid in the bottles.

qq. Ball half full of water, made in the tubes, which are attached to the tubes *ss.*

rr. Hydro-pneumatic trough.

sss. Tubes which go from the empty part of the bottles and of the receiver, and the other end of which opens into the water.

xx. Perpendicular tubes descending into the liquid in the bottles.

Figure 2, represents distillation with the sand-bath by the hydro-pneumatic apparatus.

The explanation is the same as that of fig. I, with only this difference, that the distilling vessel is a receiver, or a jug with a long neck; and that the last vapours, or incoercible gases, are lost in the air, from the extremity of the last tube.

Figure 3, represents a hydro-pneumatic trough.

aaaa. Hydro-pneumatic trough.

bb. Excavation, or vacancy under four-fifths of the capacity of the trough.

cc. Portion of the trough hollow through its whole height.

dd. Upper part of the portion *cc*.

ee, A small board laid across part of the portion *dd*.

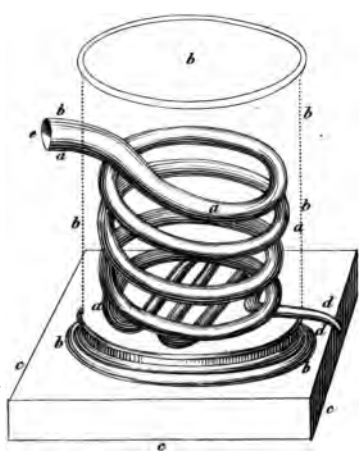
f. Hole in the middle of the board.

g. A hole at one end of the board.

hh. Upper part of the trough, not more

Fig 1

Fig 2



than two or three inches in depth from the brim.

ii. Depressions, or hollows, to receive the curved necks of bottles, or the curved ends of tubes.

kk. Vessels inverted on the surface of the trough.

PLATE IX.

Figure 1, represents the boiler of an alembic.

aaa. Body of the boiler.

bbb. Convex bottom of the boiler.

c. Aperture by which the liquid for distillation is poured in.

dd. Handles to lay hold of and move the boiler.

ee. Mouth of the boiler.

Figure 2, represents a worm.

aaa. The worm.

bbb. Cask in which it is placed.

ccc. Stand on which the cask, containing the worm, is placed.

dd. End, or mouth of the worm, from which runs the liquid under distillation.

e. Upper aperture of the worm, which receives the end of the neck of the alembic.

Figure 3, represents a furnace with an alembic and a worm.

aa. Furnace in which the alembic is fixed.

bb. Body, and upper part of the boiler.

cc. Aperture by which the boiler is filled.

dd. Head which covers the boiler.

ee. Neck of the boiler.

ff. Junction of the neck with the upper end of the worm.

gg. The worm, represented by dotted lines in the cask.

Plate 10 M.

Fig 1

h. Lower end of the worm.

iii. A pipe to receive the superabundant water of the cask in which the worm is placed.

kk. A pipe intended to convey cold water into the cask.

ll. The cask in which the worm is fixed.

mm. The stand which supports the cask.

Figure 4, represents the interior of the furnace.

For the explanation, see Plate V. fig. 1.

PLATE X.

Figure 1, represents a calorimeter.

aa. Envelopes of the calorimeter.

bb. Covers of the three spaces of the calorimeter.

c. Cock and pipe for discharging the melted ice from the third space.

d. Cock and pipe for discharging the melted ice from the middle space.

e. Vessel to receive the water which runs from the middle space.

f. The stand.

gg. The general cover of the whole calorimeter.

Figure 2, represents a vertical section of a calorimeter.

aa. Exterior space filled with pounded ice.

bb. Middle space filled with pounded ice.

cc. The central space, separated from the middle one by an iron grating.

d. End of the channel by which the melted ice of the middle space is discharged.

ee. The bottom of the grate, which holds the ice of the middle space.

f. Cover of the central space.

gg. The top of the calorimeter covering the three spaces, and charged with ice.

kk. Channel for discharging the melted ice of the third space.

ii. Top of the cover of the third space, charged with ice.

Figure 3, represents the internal grating.

T. Gillet, Printer, Wild-court, Lincoln's-Inn-Fields.

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